Re-Engineering the New Product Introduction Process:

Report 1

Executive Summary

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Submitted

7th June 1999

Submission in partial fulfillment for the degree of Doctor of Engineering

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Declaration

The work contained in this submission is entirely the work of the author, unless otherwise acknowledged in the text, and none of the work has been previously submitted for any other academic qualification.

All sources of information have been acknowledged by means of reference.

Chris Holmes

June 1999

Abstract

This paper is the executive summary for the research project 'Re-Engineering the New Product Introduction Process.' The project is made up of a number of portfolio submissions describing differing areas of the research. The key reason for the research was to identify a way in which a case study company could radically improve its time to market for new products by improving the process followed.

An action research methodology was employed and project team used to aid the development and validation of the process and supporting tools. The result of the work was a proceduralised process for the introduction of new products, coupled with detailed supporting tools and techniques. This paper summarises the details of the new process and describes the supporting projects. The levels of validation and implementation for all the projects are also described as these were at differing levels of implementation within the case study organisation.

Acknowledgment

The author would like to thank those who aided him on the project within the Case Study Company, without whom much of this research would not have been possible. The author would also like to thank Mr. Baback Yazdani whose mentoring and advice led to the fruitful conclusion of the research. Finally the author would like to thank his partner, Claire Bainbridge for her support and advice during the time period of this research.

The key conclusions from the project are given in section six, and section seven provides the references for this report.

1.1 Reason for the Research

In order to improve competitiveness, organisations are now looking to the product development process to deliver major improvements in terms of time, cost and quality (Cooper, 1993; Smith & Reinertsen, 1991). This, originally thought difficult to manage and control process, has been changed in a number of organisations and has yielded dramatic results (Stalk & Hout, 1990; Gregory & Rawlings, 1997).

There has been much literature produced upon the benefits of reducing lead time in the product development process (Stalk & Hout, 1990; Smith & Reinertsen 1991; Dimancescu & Dwenger, 1996; Cooper, 1993) with some key workers believing that the focus on lead time will also yield improvements in terms of cost and quality (Stalk, 1988; Clark & Fujimoto, 1991). This research focuses on the needs of one particular division of a multinational organisation to reduce the lead-time for its product development process.

The key reason for the need for this research to be carried out is that it focuses on 'how' to make the change for the benefits of reduced lead-time to be realised. It focuses on the development of a new process for product development, and the associated tools and techniques to facilitate the process. This has been an area that has been neglected by much of the literature as this is the hardest area to research and change. One of the key reasons for this is that the changes made tend to be very company specific, i.e. the changes will suit a particular organization and a particular point in time, given particular circumstances. A different organisation employing exactly the same methods may not achieve the same results.

1.2 Background to the Case Study Company

The Case Study Company designs and manufactures aerospace flight control systems. It is part of the aerospace division of a large multinational corporation, whose other core business is automotive products. The sales for the company in 1997 were close to £100 Million. The company is based in the West Midlands and employed about one thousand people in 1994. The engineering department comprised of about one hundred and twenty engineers, organised in a matrix type structure.

The Company's mission in 1994, at the outset of this project, was to become a systems integrator, rather than just a component supplier. Its success depended upon realising optimised functional performance through the integration of flight control components by
mechanical
physical, electronic or software means.

1.3 Project Objectives

The objective of the research project was to develop a process for the collaborating company to radically improve its new product introduction process in terms of lead-time. Whilst the key focus was the development of a process for improved product development, the scope of the project required that other areas were examined in order to achieve the overall objective. In order to identify these areas a framework for splitting the areas of work into sub projects was developed and used. This is shown in Figure 1. This included research into areas such as the organisation structure, the sharing of knowledge, the use of performance measures, and the management of process change. A detailed explanation of the framework is given in the submission entitled 'Key Infrastructure Requirements for NPI' (Holmes, 1998l). These were necessary to achieve the overall objective.

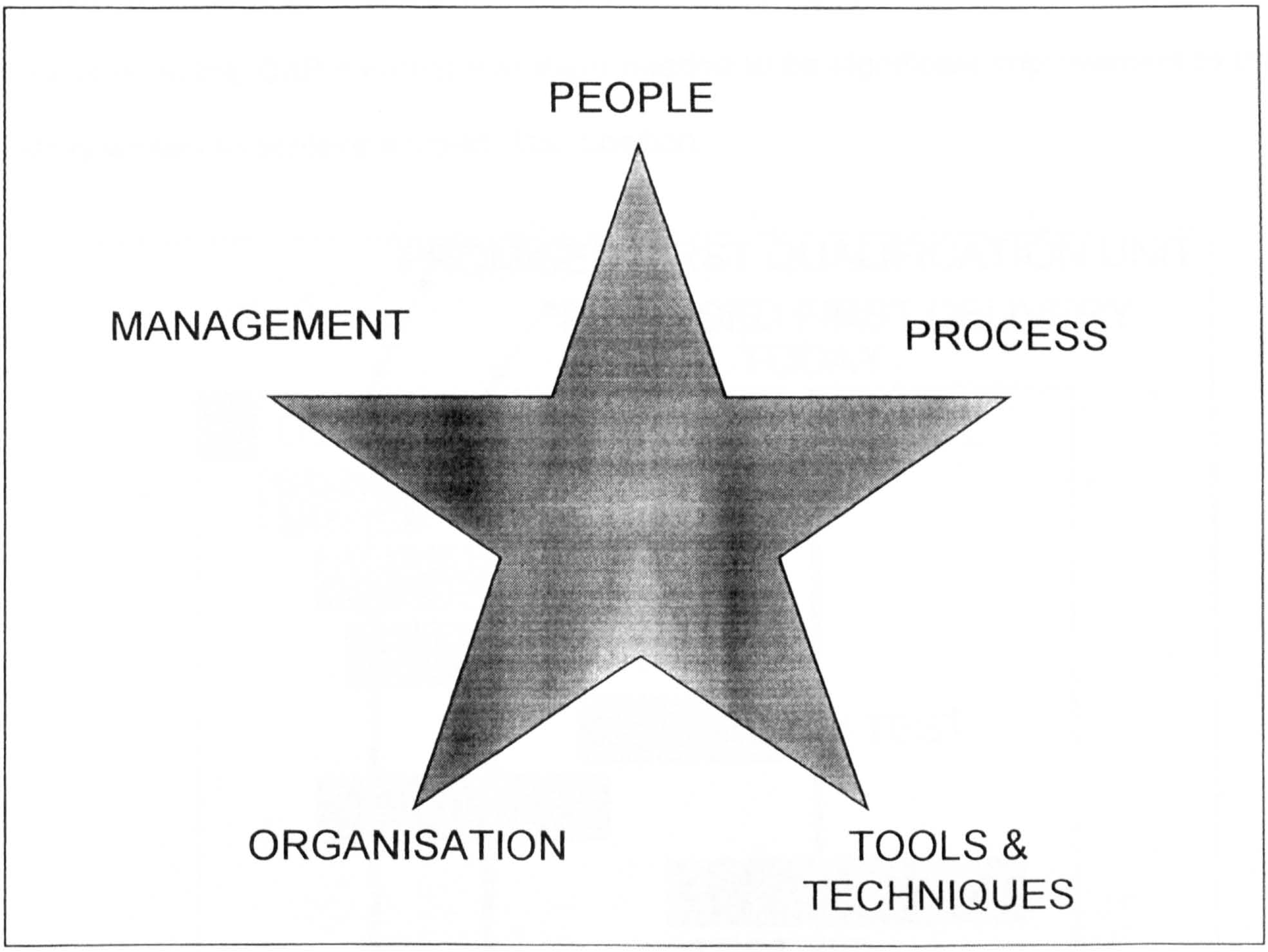

Figure 1. The Research Framework.

The scope of the research involved the RE being responsible for the development of the process and associated tools and techniques. The responsibility for the actual implementation lay with the case study company, with the RE acting as observer.

1.4 Existing Level of Performance

The need for the company to improve its competitive position was recognised by senior management and the product introduction management (PIM) project was included in the company's competitiveness achievement plan (CAP). This document sets out the key improvements that are to be made to the organisation and process that will realise significant improvements in the competitive position of the company. It also allows resource to be dedicated to the achievement of the programme. For the PIM project to be included in the CAP it meant that there needed to be significant improvement to the existing system to achieve a world class position.

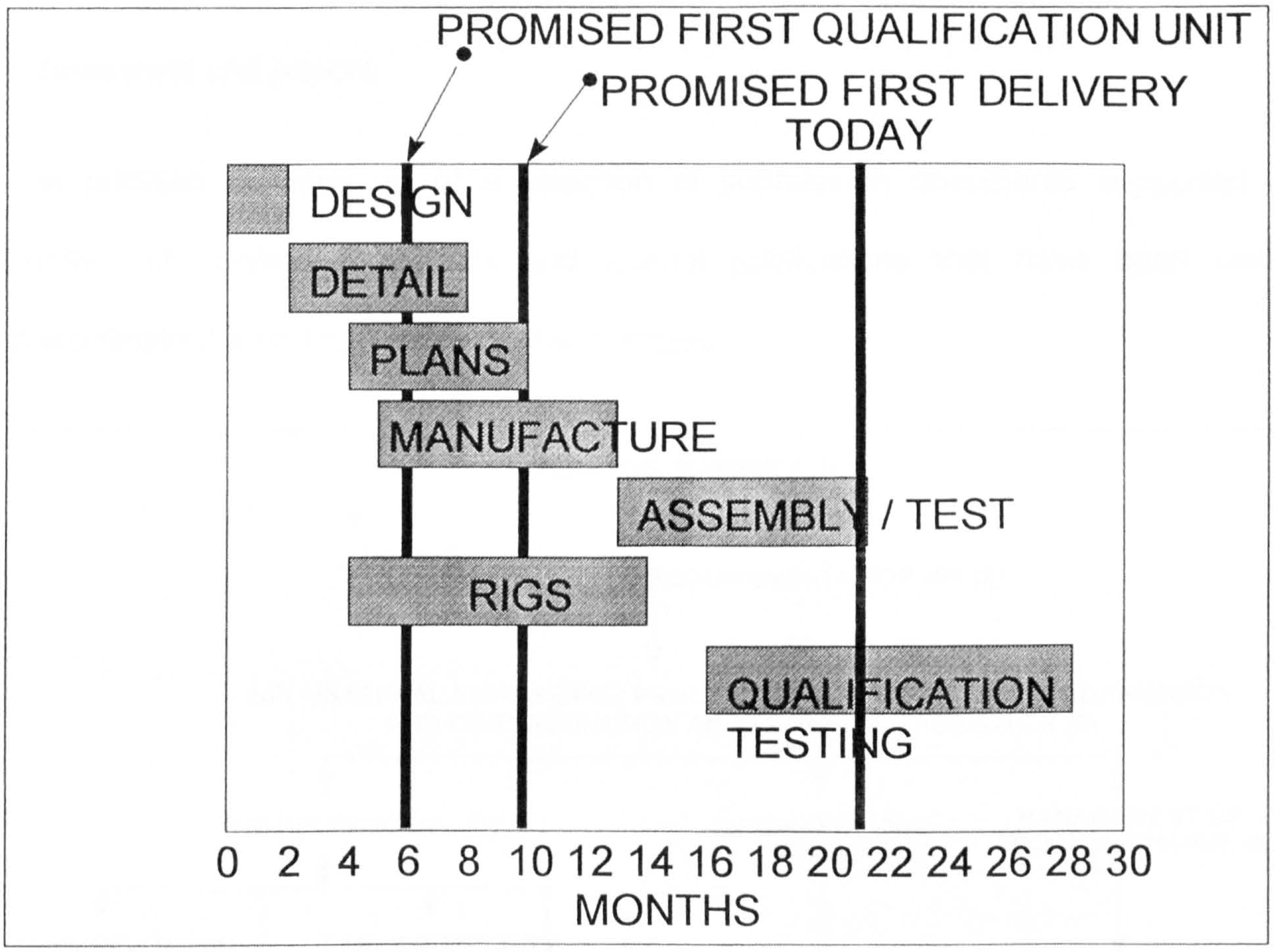

Figure 2. Review of a Typical Components Timeline

The timeline in Figure 2 shows the typical performance of the organisation in meeting customer targets in terms of lead-time when the project commenced. As can be seen from the diagram the system was late in delivery to the customer, with some qualification testing still needing to be completed. The delivery of product introduction projects late was normal for the company.

1.5 Structure of the Portfolio

The suggested reading order for all the papers and submissions is given in Figure 3. This gives the reading order but not the completion order of the work. The reading order begins with the Executive Summary and then cascades through the various submissions and papers.

The portfolio is made up of a selection of submission documents supported by a number of conference papers and journal publications that have been used to disseminate the findings of the research project.

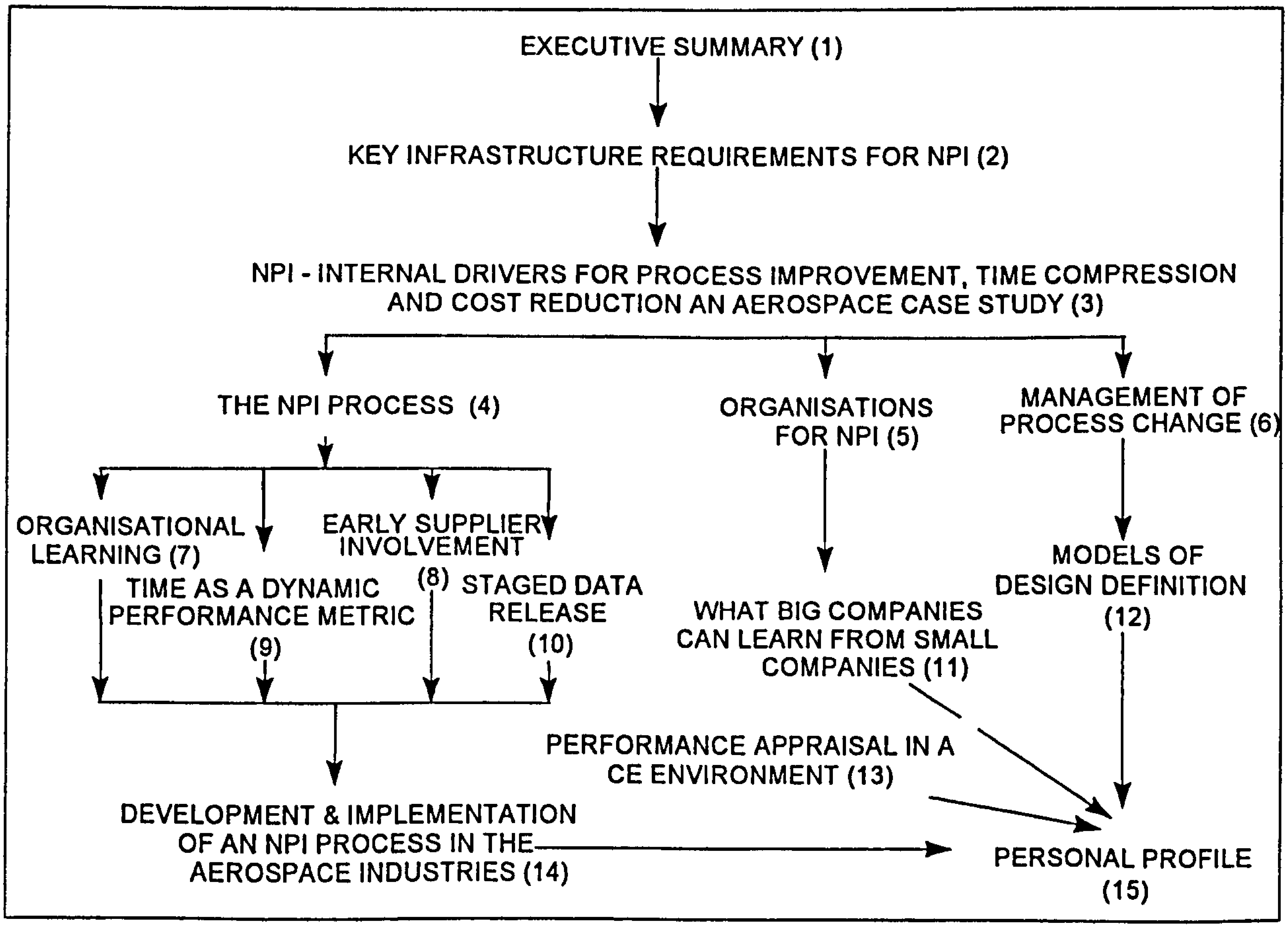

Figure 3. Reading Order for the Portfolio and Submission Number

2 The Research

This section gives an overview of the research project, the research methodology applied, the project timeline and a review of the problems encountered whilst completing the research.

2.1 Overview of the Research Project

Due to competitive pressures the Case Study Company was interested in focusing upon the new product introduction process, both in terms of time and cost. They had suffered some financially damaging retrofit projects due to qualification testing not being fully completed on components released into service. These components had been released with a short life whilst the long life qualification testing were being completed. The company had also managed to gain an order from Boeing through the delivery of a working prototype at the bid stage, rather than the traditional paper designs. A major competitor had achieved a major programme in delivering systems for the Boeing 777 in a substantially shorter lead-time than the industry norm, undermining the Case Study Company's position in the market. In view of these three points, a major change programme was launched, with time to market being the focal point. The programme was used as the case study for the research. The research engineer commenced work upon the research in October 1994.

The RE was involved at a very early point in the programme. This was focused upon bringing research material to the specification meetings and aiding in the production of the project specification for the high-level project team. The RE was also involved in the project launch day by giving benchmark information, based mainly on the work of Stalk and Hout (1990).

The project was then launched, with a full time project team being given the task of identifying, at a 'high level', the key issues to be addressed in reducing the lead time for new product introduction. This was also to include analysis of what would be required to deliver a working prototype at the bid stage for all contracts. Also included in the project specification was the requirement to map the current process, and to identify the process and timelines of two recent projects. These were to be used as benchmark data for the implementation of the new process.

The RE was initially part of the team defining the high-level product introduction process. This work involved the collection of data from members of the engineering department, and the generation of the existing process map. The RE led twelve interviews out of the thirty-three people identified and also carried out the analysis of the interviews by identifying the key factors in both problems with the current process and the identification of proposed solutions for the new process. This information is described in detail in the submission entitled 'Report 3: New Product Introduction-Internal drivers for process improvement, time compression and cost reduction: An aerospace case study (Holmes, 1998v). This information was then fed back to the project team to be used in the definition of the new process.

During these interviews it was realised that the project aims were comprised of a number of different elements. The focus on lead-time reduction, whilst allowing systems to be delivered on time to the customer, would not in itself realise any additional benefits, in terms of quality. Hence the target of delivering fully qualified components to the customer was set as the new target. In order to achieve this the whole NPI process from concept design to completion of qualification testing would require investigation.

This would go someway to eliminating some of the expensive retrofit programs that had plagued the company in recent years.

The requirement of the project specification to design a process to allow the delivery of working prototypes at the bid stage was deemed to constitute a separate project. The project team and the company management decided to implement this project once the process for delivering a system from contract award to completed qualification had been completed.

The need to complete qualification testing before release to the customer required that all of the three phases identified (concurrent definition, prototype production, assembly, test & qualification (Holmes, 1998iii)) within the process be shortened. The first phase, concurrent definition involved the process moving from contract award to delivering a complete set of manufacturing instructions to production. The second phase was the production of the test and qualification units (prototype production). The third and final stage was the production testing and qualification testing of the units (Assembly, Test and Qualification (ATQ)). A high level process for these three activities, recommending sweeping changes to the current organisation and process, was then prepared and delivered to the project owner and steering group (Holmes, 1998iii, Holmes, 1998ii) in December 1995 / January 1996.

The high level process had been designed by the project team with the key focus being on the development and identification of the generic activities that were serial in terms of data transmission, and those that had some form of overlap, and could embrace techniques such as concurrent engineering. Also identified was the need to remove queuing time from the process. This being identified as a major cause of delay particularly from the delivery of a manufacturing package to production, and then the delivery of a full kit of parts to assembly. The need to bring the whole process under the control of the product introduction team was also identified as a major factor in achieving the required reduction in lead-time.

The high level process had been designed, but many of the requirements of the process still had to be developed. These included the development of a fast track system for the release of information, the inclusion of manufacturing knowledge in the design phase, and the greater use of the supply chain. These had all been proposed as requirements, but there were no actual techniques in existence to make these happen within the organisation. This led to the detail design project, led by the RE.

2.1.1 The Detail Design Project

The detail design project was launched in April 1996, with the RE project managing all of the detail design projects and responsible for the linkage of the lead time reduction project to the rest of the change programme (EPD, Document Management, Organisation, and IT Integration.) The RE was responsible for the developing all the project plans and low level work packages detailing the resource needs of the projects and the expected deliverables. This was working under a programme manager responsible for the delivery of the whole change programme.

The detail design projects were implemented one at a time, the first being the concurrent definition phase. The target for the end result was the implementation of a set of detailed generic process procedures. This would involve the development of process tools and techniques, and the successful piloting of these, so they could be used as tools to support the high level generic process. The projects to be completed are shown in Figure 4. This also shows the projects that the research engineer was responsible for and the linked projects that were conducted by the organisation.

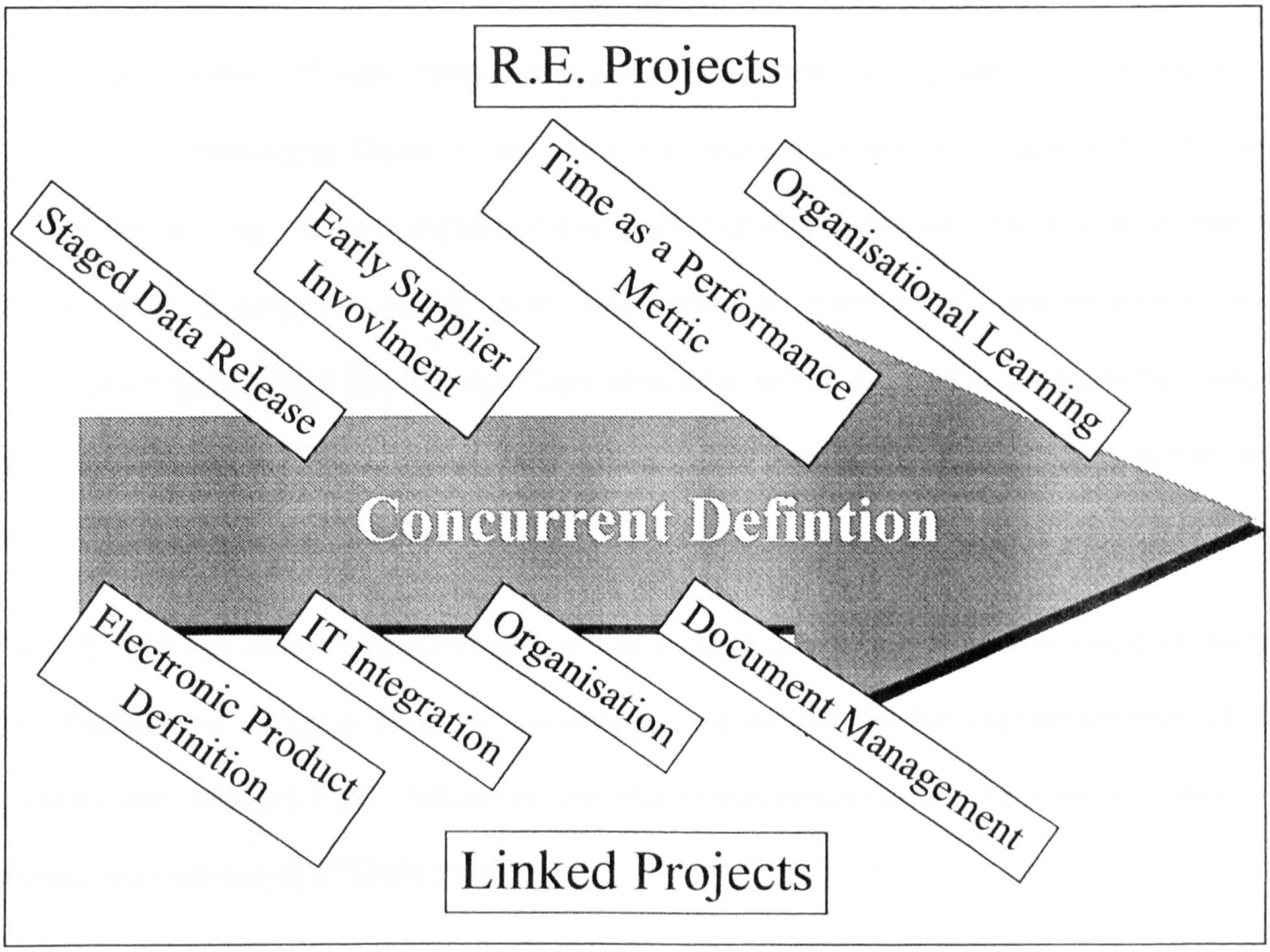

Figure 4. Detail Design Projects.

The project teams led by the RE took the form of part time teams, with the RE developing the detail of the work and using the project team for validation of the work through a series of approval meetings. The projects were run concurrently as this was required for the development of the new process – some tools and techniques would have a significant affect upon the detail of the process e.g. staged data release. A detailed review of all the projects is given in Section 4, where a detailed review of the project's aims, methodology and resulting validation is given.

During the completion of the detail design projects and the process redesign projects, the whole Corporation merged with a US based Corporation. This was predominantly focused on aligning the two companies automotive businesses. The merger was announced on the 31st May 1996. Initial effects upon the RE included the resignation of the Divisions Managing Director, who was the sponsor of the RE's research. This was quickly followed by the resignation of the plant manager who was the industrial mentor of the RE. During November and December a number of redundancies were announced, throughout the management structure, which led to the programme manger and a number of the RE's project team being made redundant. The process owner also left the company at this time.

The RE and the remaining members of the project team, including the head of design and the head of product integrity, continued to push for the full implementation of the process into January 1997. However with the implementation of a new organisation the project was canceled in March 1997.

2.2 Project Timeline

The actual project plan is given in Figure 5. This shows the research activities against the span of the total research project. This can be compared against the initial project plan presented in 'Key Infrastructure Requirements for Successful NPI' (Holmes, 1998i). Key differences between the planned work and the actual work are the time scales and the addition of some areas of work. The major difference in the time scales is the actual research project took closer to four years rather than the planned three years. Reasons for this include the organisational changes that occurred within the company during the course of the research project, and the addition of various areas of work. An example of this is the work done on examining performance appraisal. This was seen as necessary under the people point of the research framework (Figure 1.). However, research showed that the scope of this project area was very large, and the area of research did not fully support the key objective of the research, the development of a new NPI process. Preliminary findings of the research carried out did result in a paper entitled 'Performance Appraisal in a Concurrent Engineering Environment.' (Yazdani & Holmes, 1998).

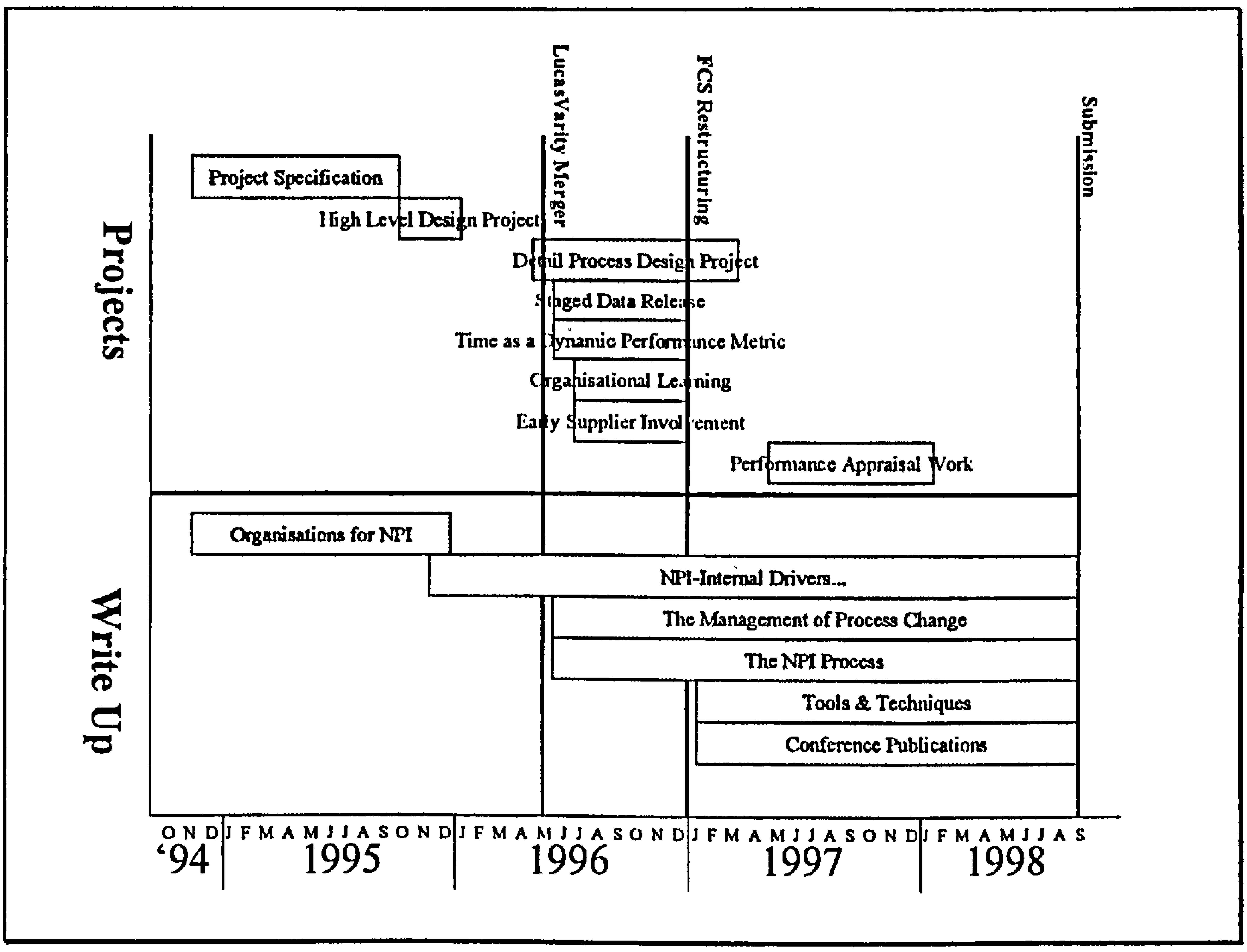

Figure 5. Actual Timeline of Research Project

Other areas of work, which contributed to the length of the research project, included work done analysing the various types of process structures that drive the new product introduction process. This work has been disseminated through conference and journal papers (See Personal Profile for Complete Listing (Holmes, 1998vii)), taking the concepts used to develop the New Product Introduction process and comparing these to other organisations.

The work on the management of process change overran the time scales allotted. Reasons for this include organisational problems, manifesting themselves in the ability to appoint a programme manger to oversee the New Product Introduction (NPI) project and the associated EPD implementation project.

2.3 Research Methodology

The aim of this research project was to develop and validate a product introduction process within an operating company. In order to achieve this goal a research methodology had to be applied that would support the research and validation of change. Hence this project was ideally suited to the application of an 'action research' methodology. Lewin (1946) characterises action research with the starting assumption 'that the social world is constantly changing and that the researcher and research are part of this change.' This is supported by the more recent work of Easterby –Smith et al. (1996) who suggest that classical action research starts from the idea that if you want to understand something well you should try changing it. Both writers focus on the concept of making change happen as being central to action research. This requires the study of the existing system, the changing of that system and the analysis of the results, making it the appropriate methodology for this research project.

Lewin (1946) suggests that the process to be followed is a cycle of planning, acting, observing and reflecting. The initial phase, planning, identifying the objective of the research – for this research project the objective would be to 'reduce lead time in the product development process.' The action phase involves the actual implementation of the change, this is then followed by observation as to what occurs and reflection as to why it occurs. This is supported by the work of Hussey and Hussey (1997) whom suggest that the main aim of action research is to enter into a situation, attempt to bring about change and to monitor the results, very similar to the plan, act, observe cycle advocated by Lewin. They also suggest that this type of research requires close collaboration between the researcher and client company. This is borne out by the detailed project methodologies described in sections 3 and 4, where the researcher led a number of project teams, composed of company employees, in order to understand the process and to seek validation of proposed changes to that process. They continue, and suggest that the full-scale implementation is normally the responsibility of the case study company, whilst the initial investigation, and pilot projects of the change process are the responsibility of the researcher – this is the path taken by the researcher in this project.

The detailed methodology for each project is given in sections 3 and 4. An example is shown in Figure 6. This shows the procedure followed for the research and development of the 'As Is' process map. Similar approaches were taken for all the projects with a series of serial activities resulting in a 'sell off' point where the new process / tool / techniques was approved. This normally involved selling the concept to the project team initially, and then, after modification, selling the concept to the applicable function(s). Once the concept had been approved then it would be documented / proceduralised. This process would normally go through several iterations to clarify all the necessary points.

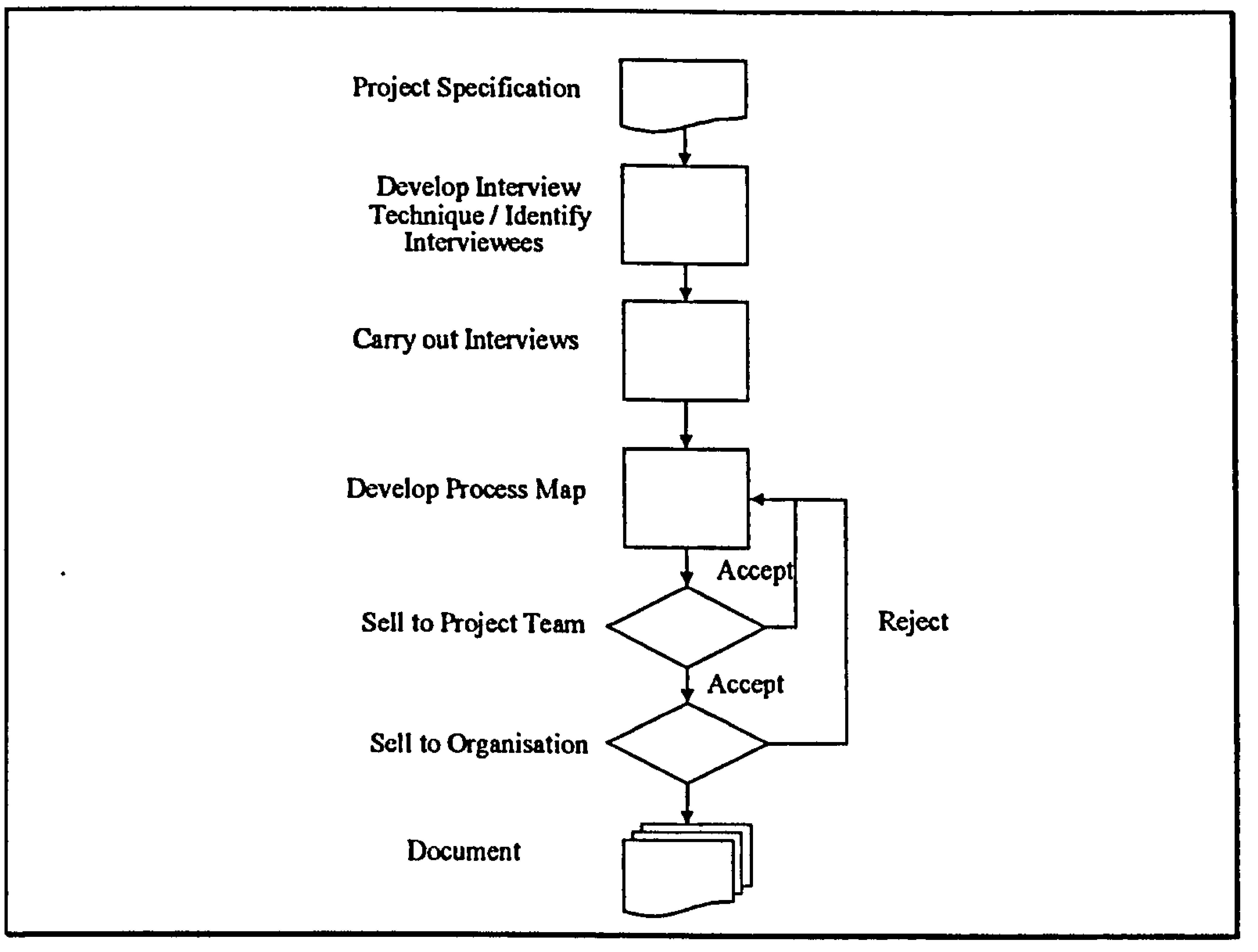

Figure 6. As is High Level Process Map Development Methodology

After the decision on the type of research methodology to apply, this had to be applied to the actual project. Various types of tools and techniques were used to collect and analyse information. The key tools used were structured interviews, process mapping, literature searches, and pilot studies. Structured interviews were used to gain knowledge as to the current product introduction process, the problems encountered, and the order of activities. This information was then used to draw process maps, which allowed the sequence of activities to be seen. The development of a 'To be' process map utilised information from the structured interviews and the application of 'best practice' from literature searches. The development of the facilitating tools and techniques followed a similar methodology.

The detailed methodology is given for each project in sections 3 and 4 and each project is explored in terms of its aims, methodology, level of validation, and results.

2.4 Problems Encountered

Whilst carrying out the research a number of problems were encountered that affected the research. These can be characterized under four different headings. These will now be discussed in more detail, with the subsequent learning associated with these problems being highlighted.

2.4.1 Lack of Clear Direction

At the outset the projects had a single focus, comprising of a number of elements this being the reduction of lead time in product development, coupled with the delivery of a working prototype at the bid stage. However, as work progressed collecting data in the high-level project design phase, it became apparent that the delivery of a working prototype at the bid stage was going to have to be viewed as a separate project. This required a different approach from the 'normal' product introduction process as it was very much tied in with the marketing / order winning business process, rather than the more technical product development process. The other reason for concentrating on the product development process was the need to get the product development process right, so that any orders won could actually be delivered on time and to the right quality, something the existing process was not efficiently and effectively delivering.

The effects upon the project team of the need to change the project scope caused a great deal of time to be lost through the preparation of presentations and reports justifying the apparent change in focus. Much literature has been produced on the subject of change management, and one of the key success factors highlighted by many authors in introducing change is the need to have a clear, defined project objective (Clarke, 1998). At the outset this project appeared to have a clearly defined project objective, but as detailed information was gathered this required change. In order to change the projects focus a great deal of time had to be spent educating and informing the project steering group as to the need to change the project objectives.

One way of dealing with this type of change project, where the detailed information is needed to fully define the scope of the project, would be to issue the project team with a broad area for examination. The project team could then define the scope of their project once they understood the existing process and problems. This would allow objectives, that were achievable and set by the team, to be the project specification.

2.4.2 Lack of Management 'Buy in'

Another oft cited comment in the literature on change management is the need to ensure that all of the senior management are fully committed to the change project, this is especially true when dealing with cross functional change projects (Blacker, 1995). At the outset of the project, the project team was informed that the senior management had 'bought' into the change project and was supporting it.

The key problem for the project team was the need to get operations 'bought in' to the proposed improvements to the product development process which involved engineering having control of the whole process from product design, through prototype production to qualification testing. This spanned a number of functions, including operations. Without the 'buy in' from operations then any improvements in lead-time would be negligible, as the process would continue to be out of engineering's control. The effects on the project team included a great deal of time spent at review meetings as each discussion with operations resulted in more information being required or a different criticism of the proposed plans. Eventually operations agreed in principle to cooperate at a high level, the problem was then passed down to the detail level design.

In order to prevent this happening again, it is critical that all the functions affected by the process change are firmly 'bought' in to the idea, that is they actually believe the change is good and will improve the business as a whole. A review of the measures of performance of the organisation could facilitate the change. Aligning operations and engineering to the same goals, as opposed to conflicting goals – detailed research revealed that the production of prototype and qualification units were measured as down time, for the machine efficiency metric, and therefore countered against the function in terms of performance measures.

2.4.3 Project Lead Time

Another area that caused problems whilst conducting the research was the timing of the various aspects of the project. The completion of the high-level design project should have been followed immediately by the detail process design project. However, due to the problems in appointing a programme manager the commencement of the detail design project did not occur until several months after the high level design project had been completed. The need to keep the change project ongoing is also cited in the literature as a key success factor in achieving change management (Farrell, 1994). This led to a large amount of time educating the various affected organisational areas that the project was still alive, and was moving into detail design and implementation phase. Again this required a great deal of time to promote the project and to make people aware.

2.4.4 Re-Organisation

The merger of the companies initially had no affect, but after several months, two waves of redundancies were applied. The first wave did not affect the project team working with the RE, but the second caused the programme manager, and various members of the RE's project teams to be made redundant. The managing director of the Division, the Managing Director of the Company and the PIM Process Owner also left the company during this time. This had a serious affect upon the research being carried out as the key sponsors of the project left the organisation. These organisational changes caused the projects to be put on hold whilst the business settled down, and a new organisational structure was developed and announced.

A key learning point~~s~~ from trying to run a change programme whilst there is a major restructuring programme being run are that it is very difficult to encourage people to embrace change or even think about the way they work whilst redundancies are being announced.

3 Key Findings

This section introduces the key findings of the research.

3.1 The NPI Process

The core innovation of the research is the development and introduction of a low-level process. The submission entitled 'The New Product Introduction Process' (Holmes, 1998iii) addresses the importance of process in New Product Introduction. This paper initially examines the benefits of a process-based organisation. It then explores the current new product introduction process at the Case Study Company, and contrasts it with a previous process re-design project. Problems with the process are identified and recommendations made to reduce the lead-time for product introductions. The key recommendation being the transfer of the process ideal to the lower levels of the engineering department. This is facilitated through the development of detailed process procedures.

3.1.1 The 'As is' Process Methodology

The methodology for the development of the 'As is' process map is given in Figure 6. This shows the methodology followed in the development of the process map. This used the project specification document as the project objective. The project team then focused on how to obtain the information. This involved the design of the structured interviews, and identification of the interviewees encompassing all the functions involved in a product introduction project.

A series of interviews was then carried out which focused on the functional activities of each individual. Questions were also asked regarding what the problems with the current process were, and what could be done to improve the way projects were developed. The results of the interviews are detailed in the submission entitled 'New Product Introduction – Internal drivers for process improvement, time compression and cost reduction: An Aerospace Case Study' (Holmes, 1998v)

The RE's contribution was the recommendation of which types of methodology would be suitable for use (questionnaires, structured interviews, etc.). The RE's also aided the development of the interview structure, and then carried out a number of the interviews (approx. twelve interviews). A core group, including the RE, then produced the 'As is' process map.

The methodology then focused on getting 'buy in' into the identified 'as is' process. This being a key requirement of any process mapping project (Hunt, 1996). The whole project team had to agree with the defined process before it could be presented to the rest of the organisation. After a number of modifications, and the agreement of the project team, the map was communicated to the rest of the engineering organisation.

The RE carried out a number of presentations to the project team and to the teams within the engineering department at the weekly team meetings, and was responsible for the establishment of the final 'as is' process map, which is documented in the process submission.

The 'As is' process map is shown in Figures 7,8,9 and 10. This shows the engineering activities and reviews that need to be addressed for a product to be released to full-scale manufacturing and to the customer. The actual process is detailed in 'The New Product Introduction Process' submission.

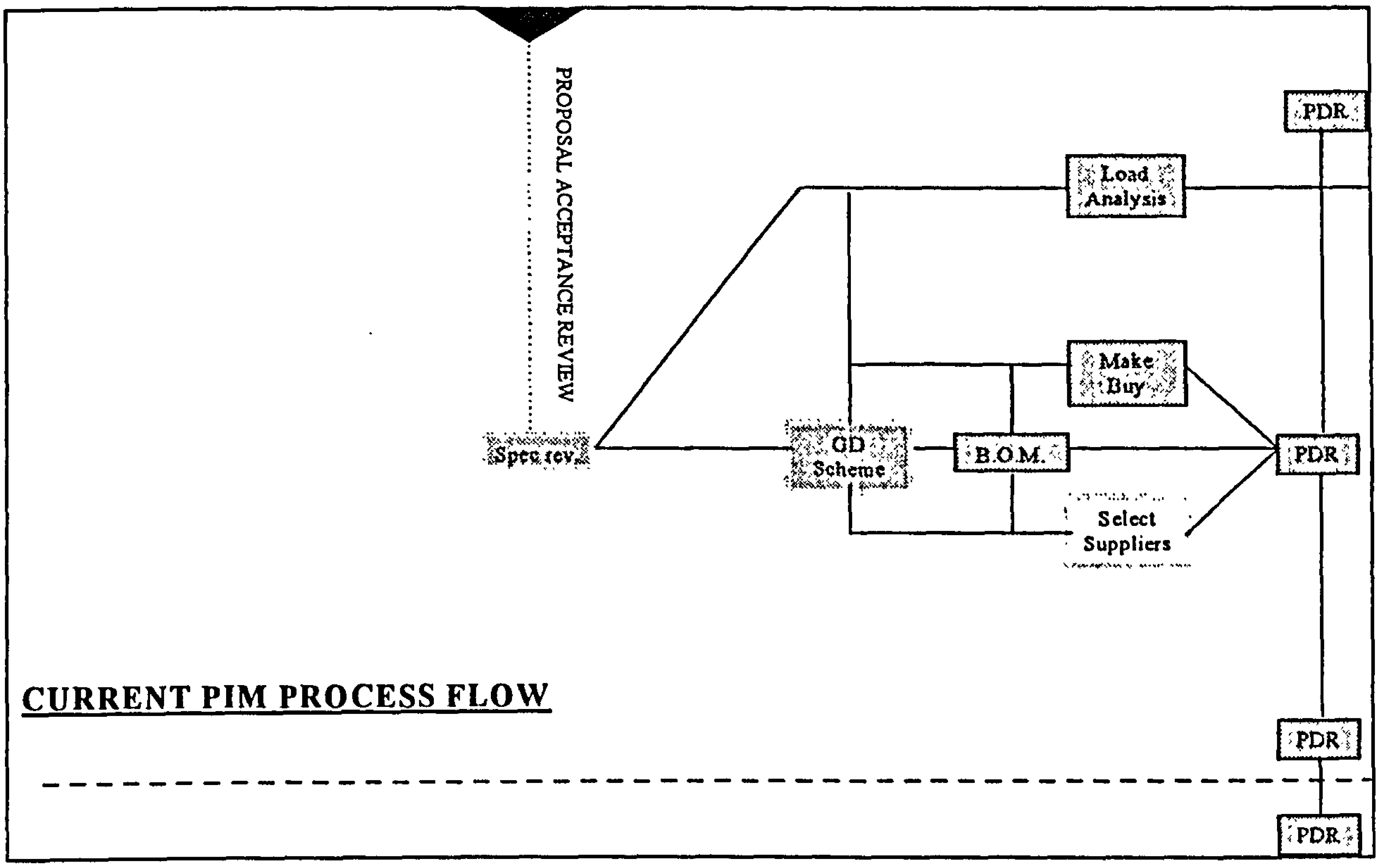

Figure 7. Current PIM Process Flow – Spec. Review to PDR

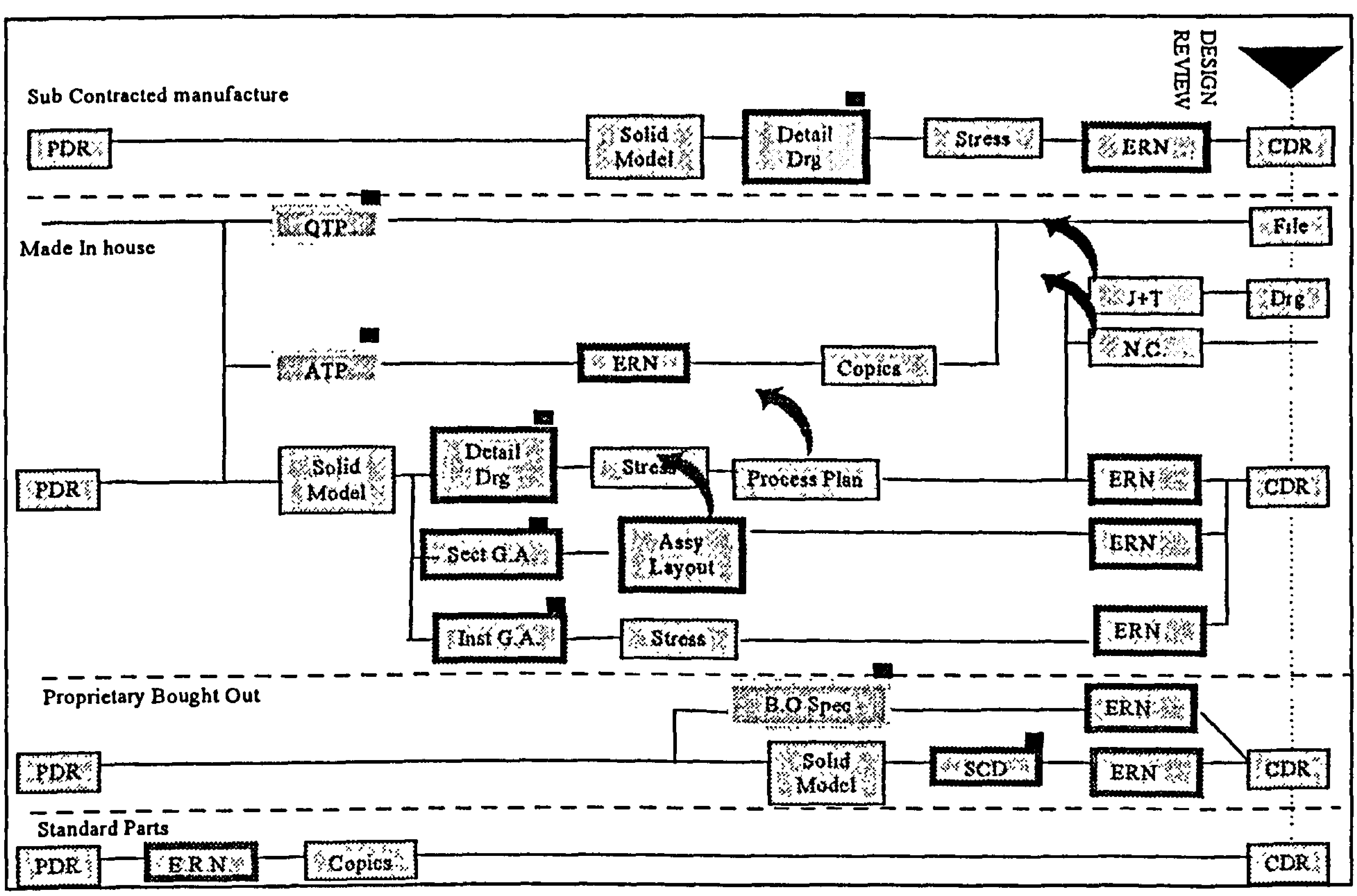

Figure 8. Current PIM Process Flow – PDR to CDR

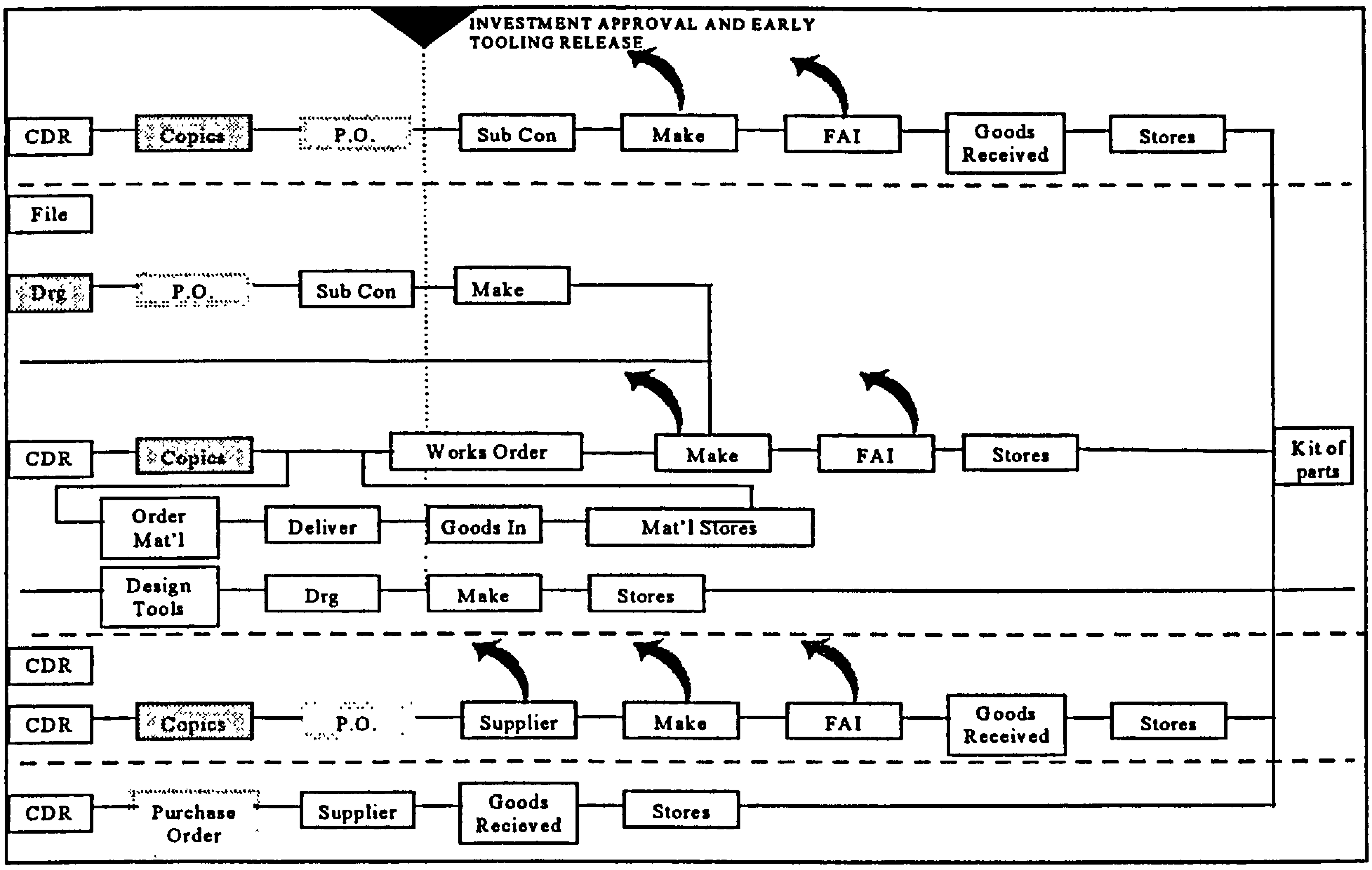

Figure 9. Current PIM Process Flow – CDR to Kit of Parts

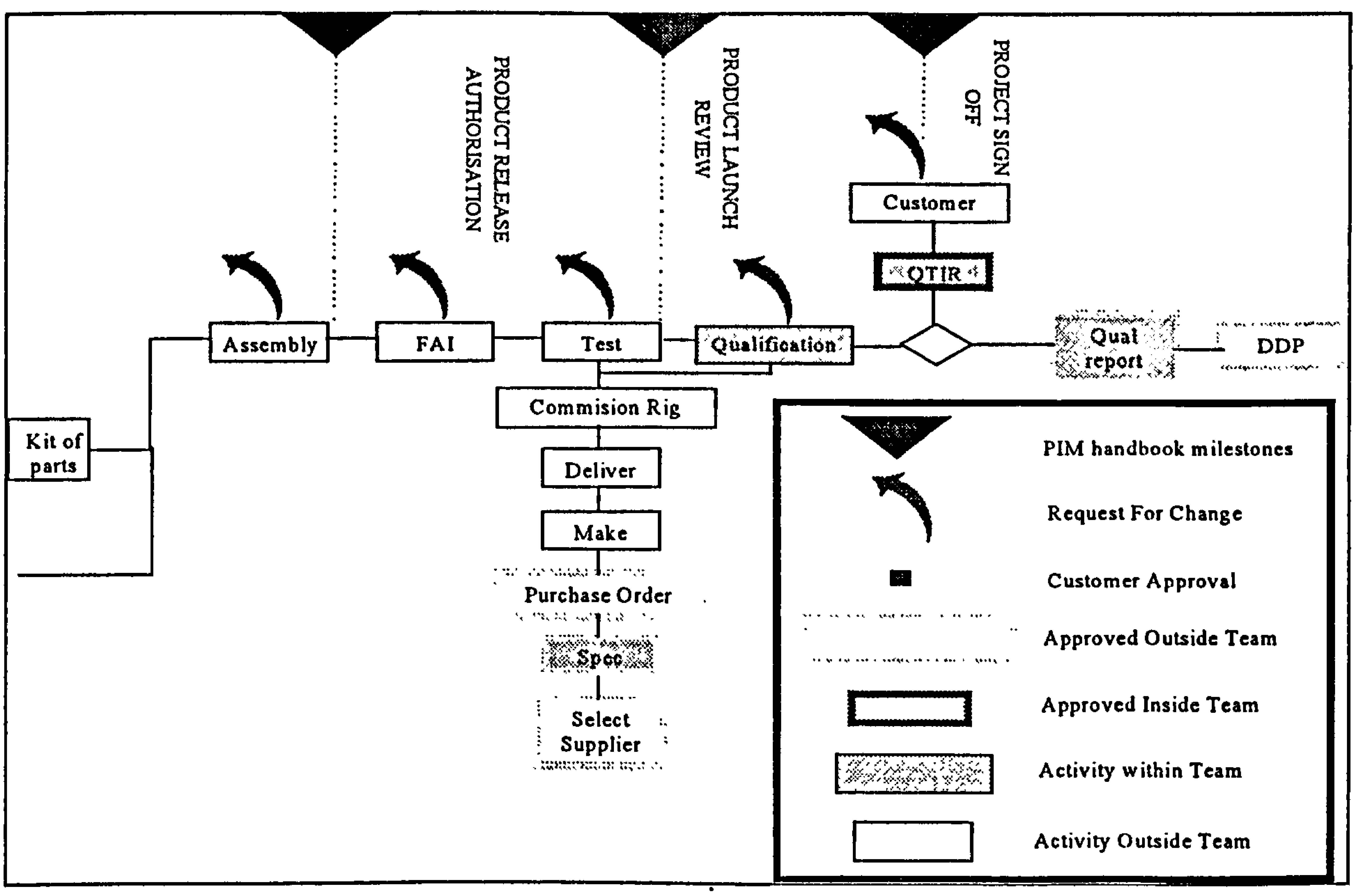

Figure 10. Current PIM Process Flow – Kit of Parts to DDP

3.1.2 The 'To Be' Process Methodology

The 'to be' process map was developed using the information gained form the structured interviews. This information identified where there were problems with the current process and also proposed recommendations as to how to improve product development. The methodology for the development of the 'to be' process map is given in Figure 11.

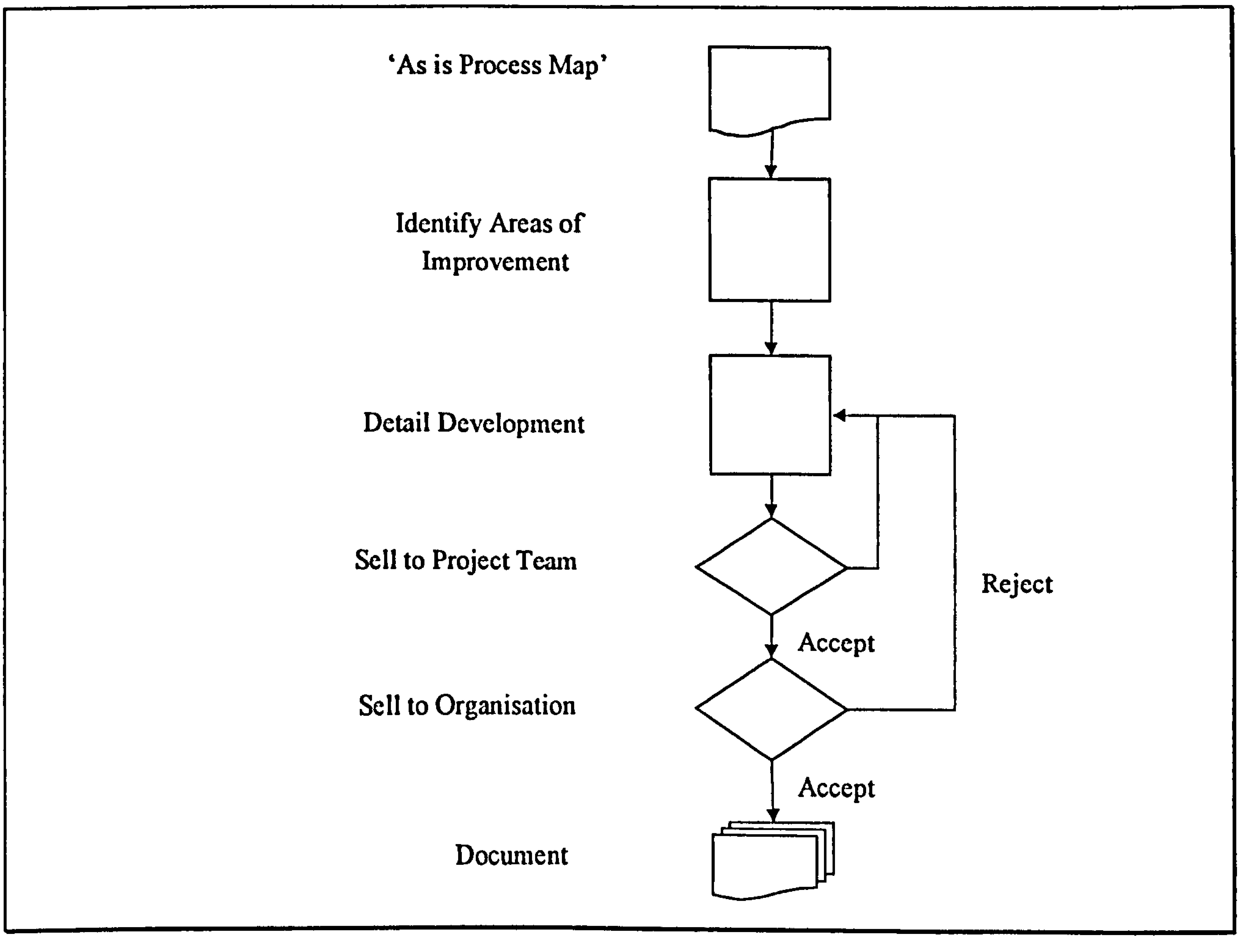

Figure 11. 'To be' High Level Process Map Development Methodology

The RE's contribution to this project was in the analysis of the interview results, giving the main areas for improvement, and in the full development of the 'to be' process map. The RE was also responsible for the final documentation of the project.

The details of the 'To be' process map are shown in Figures 12,13 and 14, the detail of the process map is given in the 'The New Product Introduction Process' submission. This includes a breakdown of all the activities and their linkage to the process activity checkpoints that were developed to facilitate the process.

A key point is that the high level 'to be' process was a recommendation from the high-level design project. None of the detail for enabling the project actually existed, and the principles required for the process to work were only defined at a top level. The detail design project required that the process be defined in detail so that the principles became methodologies that could be implemented.

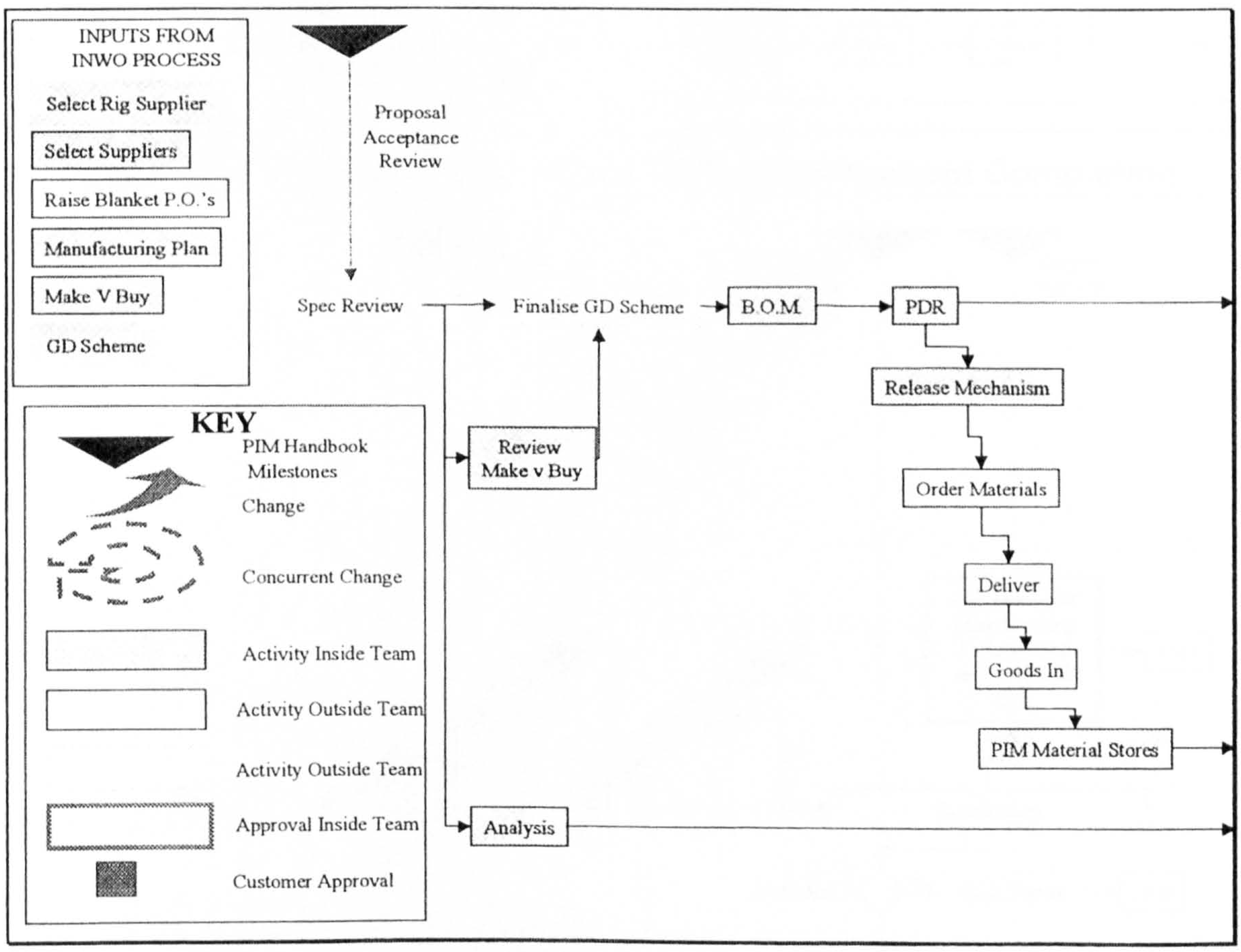

Figure 12. 'To be' Process Flow – Spec. Review to PDR

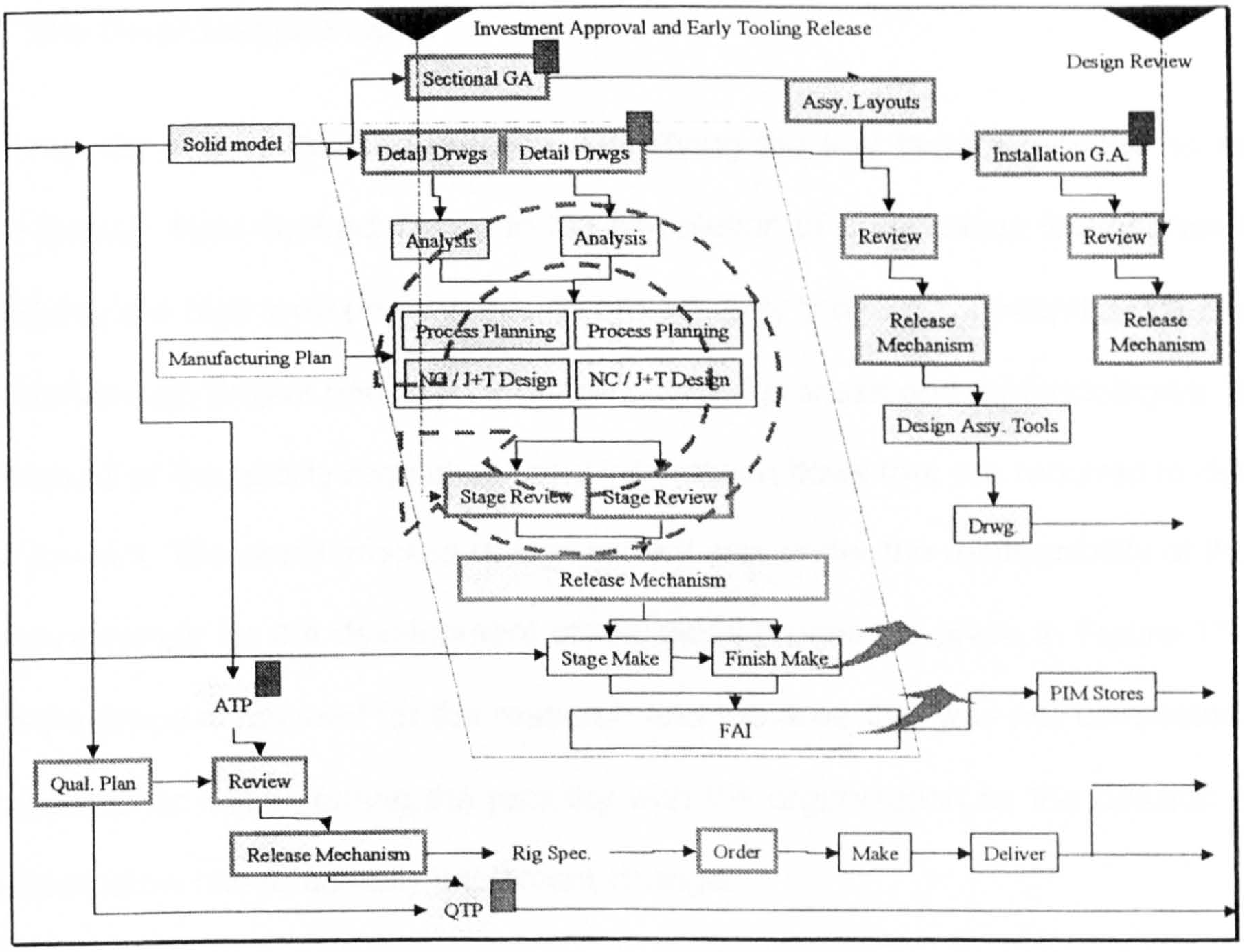

Figure 13. 'To be' Process Flow – PDR to Component Completion

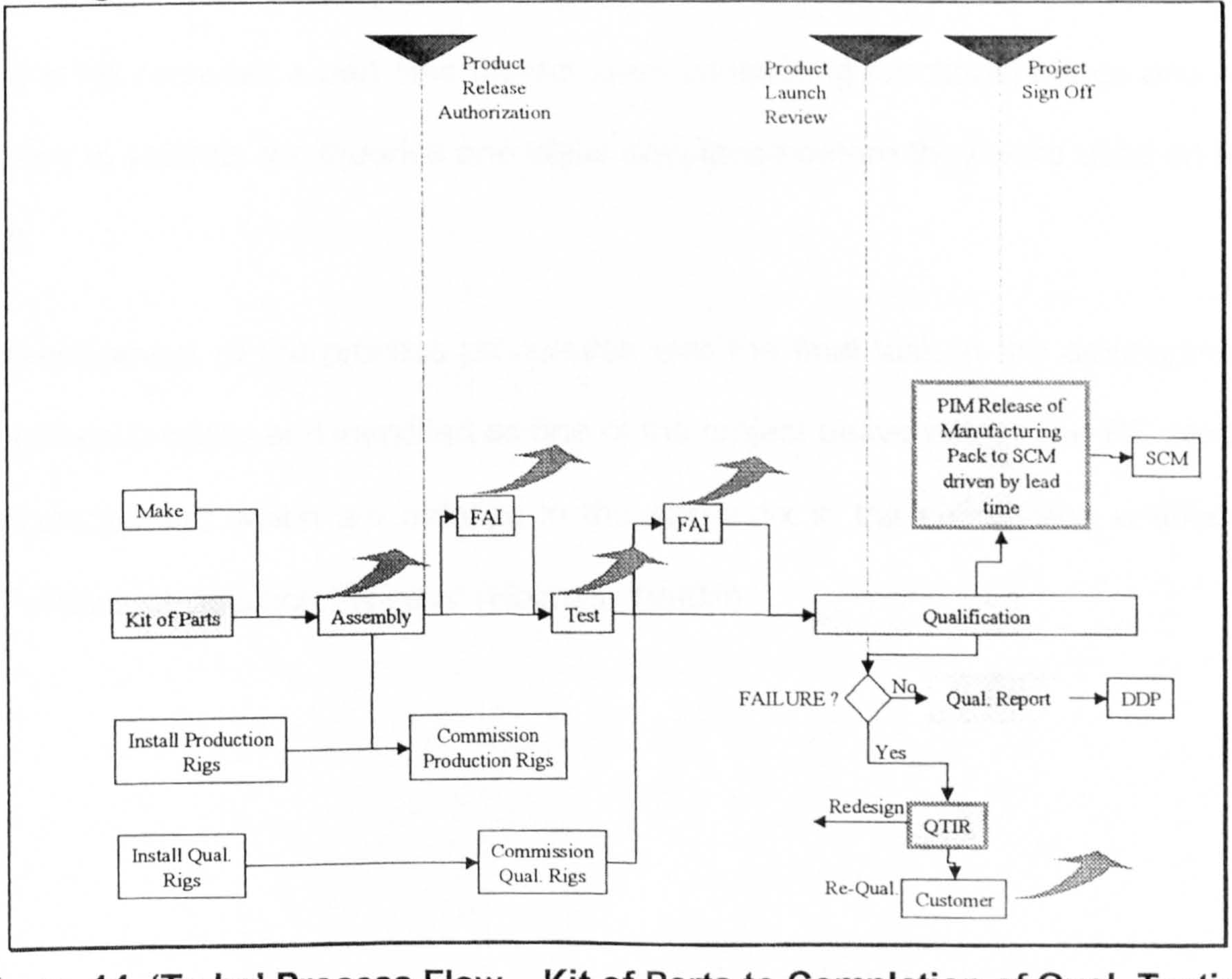

Figure 14. 'To be' Process Flow – Kit of Parts to Completion of Qual. Testing

3.1.3 The Detail Design Project

Whilst the need for a detailed process, identifying the key factors required to take a project through from contract award to the completion of qualification testing, had been identified by the high level process design project, only broad recommendations existed. The detail design project had to provide the detailed process and methodologies, taking into account all the quality regulations and information flows that are required to develop a new product. The detail process design project was under the responsibility of the RE. The methodology for the development of the detail process is given in Figure 15. This shows the process followed for the research and the area that was not completed. The responsibility for implementing the pilot lay with the organisation as the position of the RE did not allow him to actually implement change.

Using the high level 'to be' process map (Figures 12,13 and 14) as the basis for the work, the RE recruited a part time project team comprising functional heads and senior engineers to validate the theories and ideas developed before they were used on a pilot project.

The development of the process procedures was the final task in the development of the low-level process and identified as one of the project deliverables. The RE produced all the procedures which are detailed in the Appendix in the submission entitled 'The New Product introduction Process' (Holmes, 1998iii).

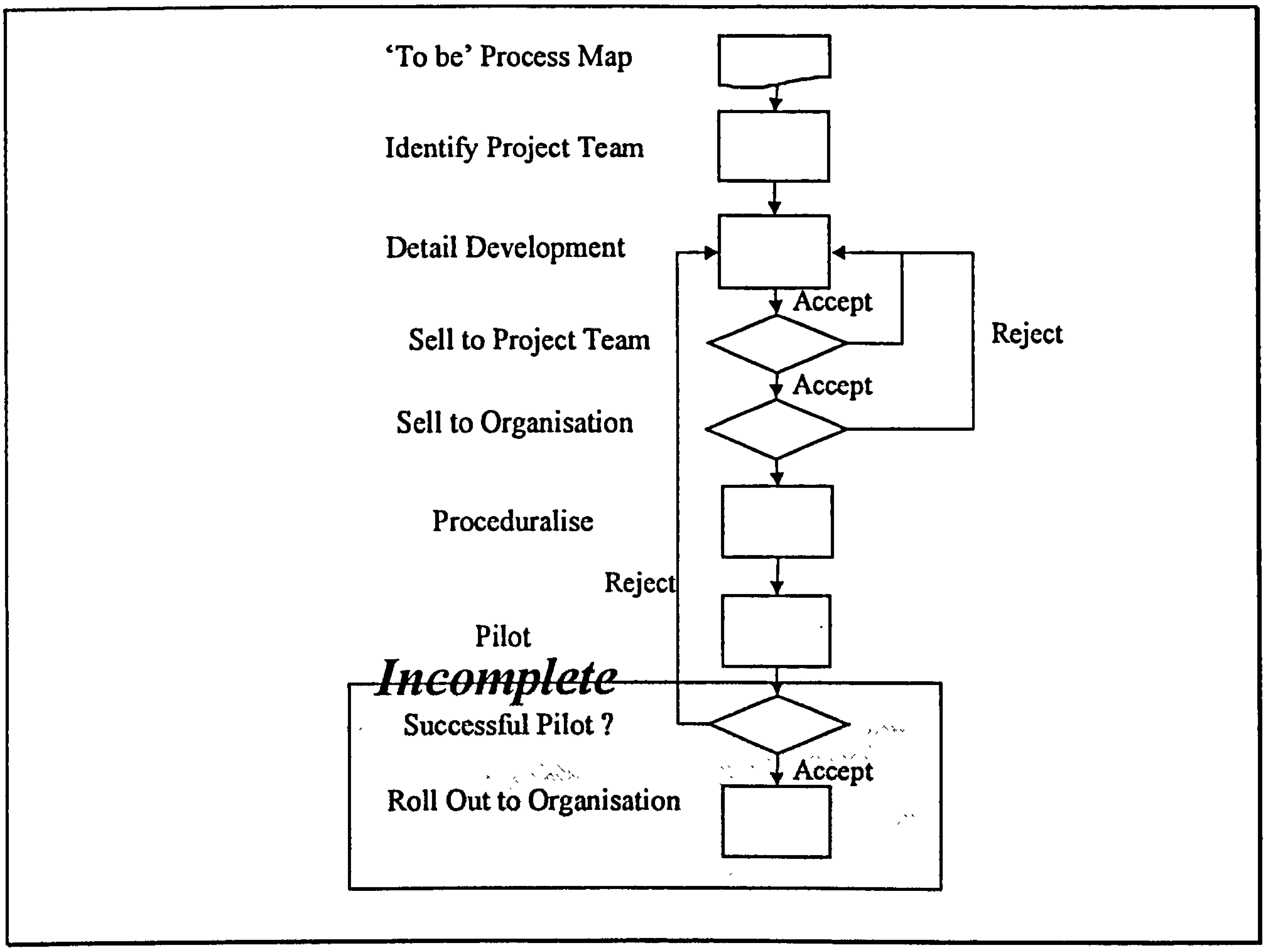

Figure 15. Detailed Process Map Development Methodology

3.1.4 Process Development Results

The production of the detailed procedures resulted in the development of a detailed process procedure, linking hierarchically to the organisations generic NPI review gates. This can be seen in Figures 16,17 and 18.

Figure 16 shows the process hierarchy for NPI. The PIM process and associated reviews are a given requirement for all the divisions within the corporation. The detailed levels of the Product Introduction Process (PIP) (Figure 17) and the Process Activity Check (PAC) points (Figure 18) are the results of the RE's research.

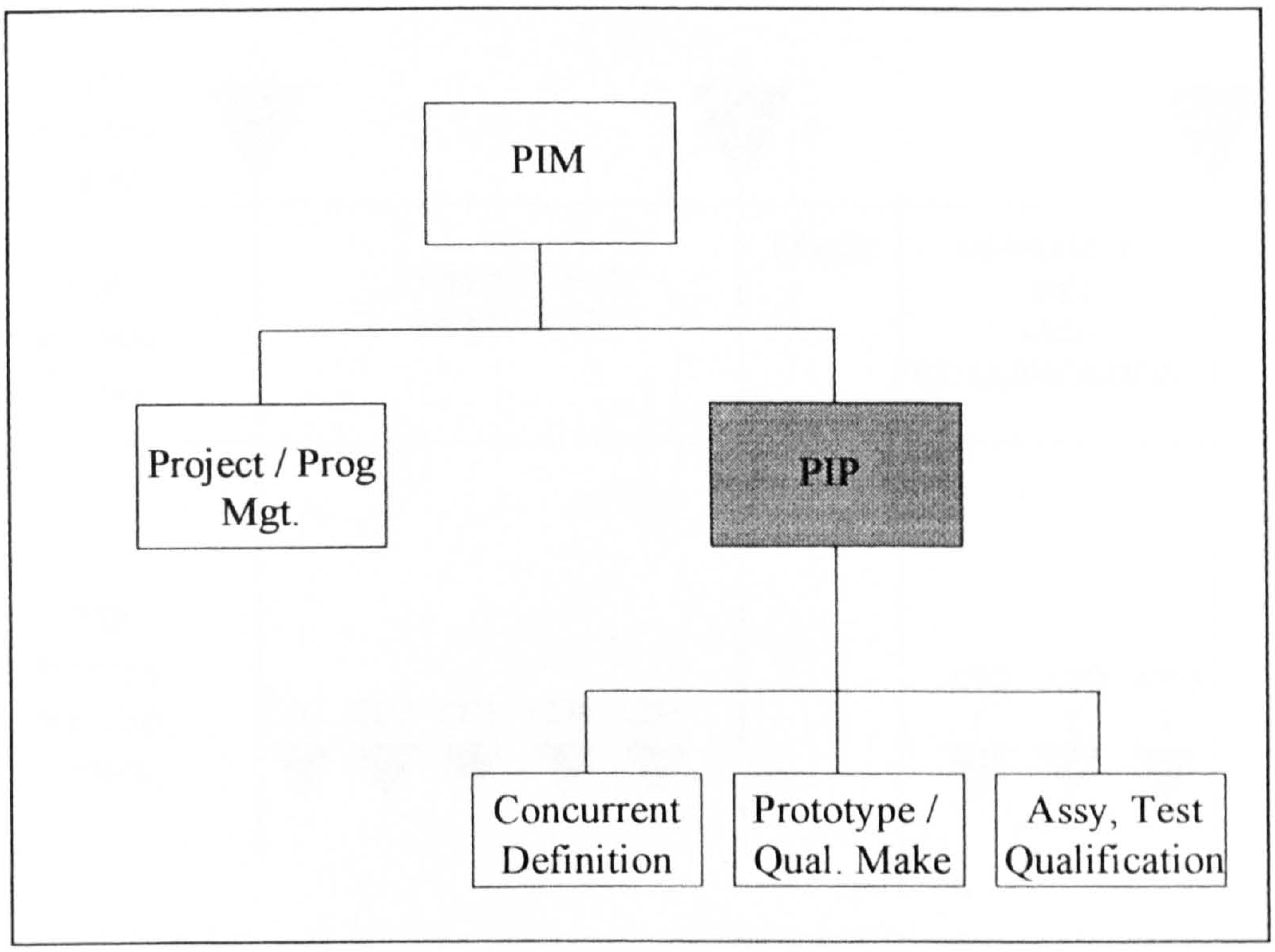

Figure 16. Revised Product Introduction Process Hierarchy

The validation of this work was demonstrated through the application of the process procedures to a live project - The Thrust Reverser programme. The project team had agreed to use the procedures as a test to demonstrate the validity of the procedures when applied to a live working project. The initial two process activity checks were applied before the organisational changes caused the programme, and pilot projects, to be put on hold.

The need to concentrate on the development of low-level processes has since been supported by the work done by the Innovative Manufacturing Initiative (IMI, 1997). They identified that most aerospace organisations had some form of high level process plan in place, and but none had actually progressed to taking the process to the engineering team level, but that this was the goal of the majority of the organisations.

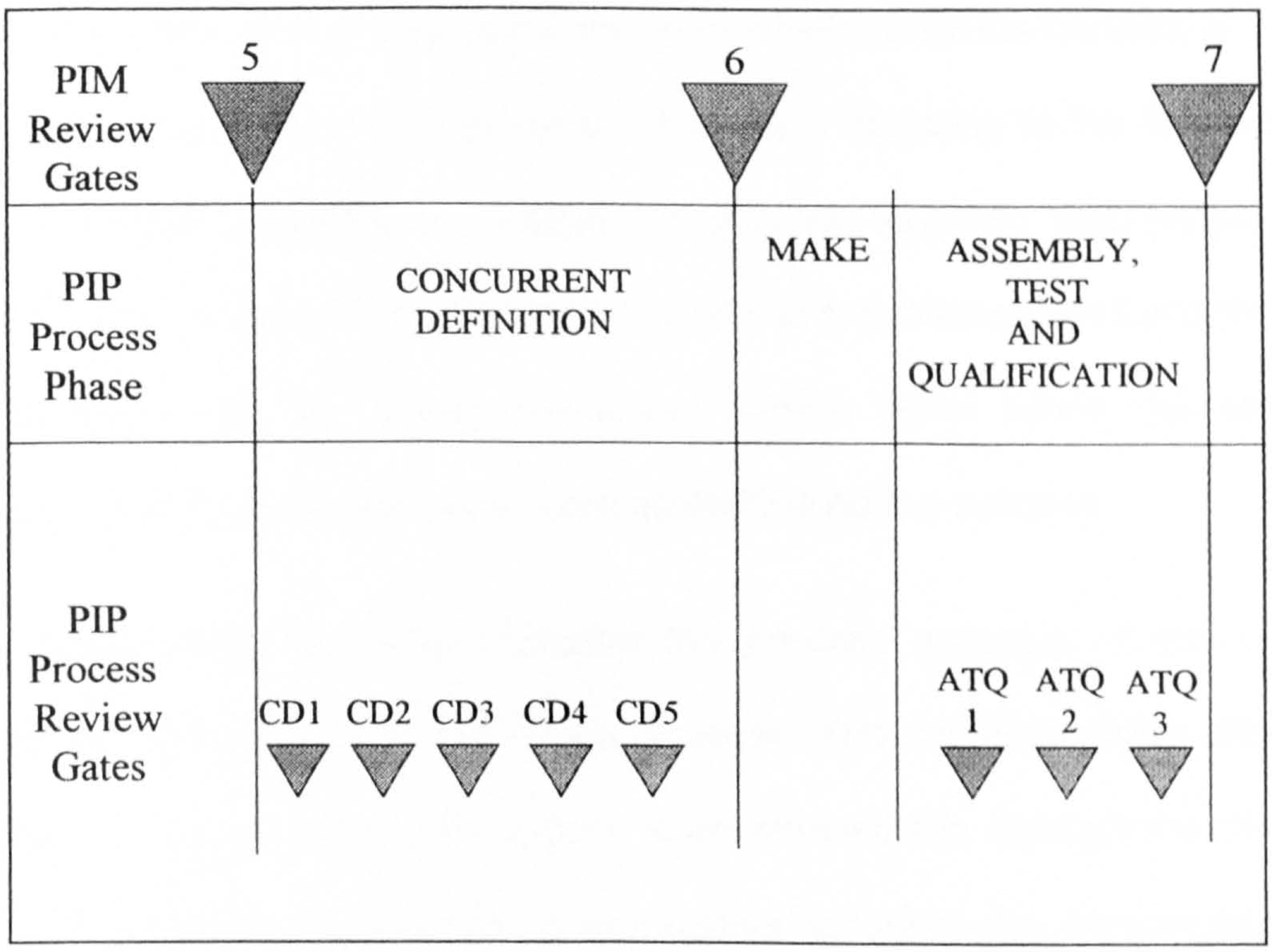

Figure 17. The Proposed PIP Process (Level 3)

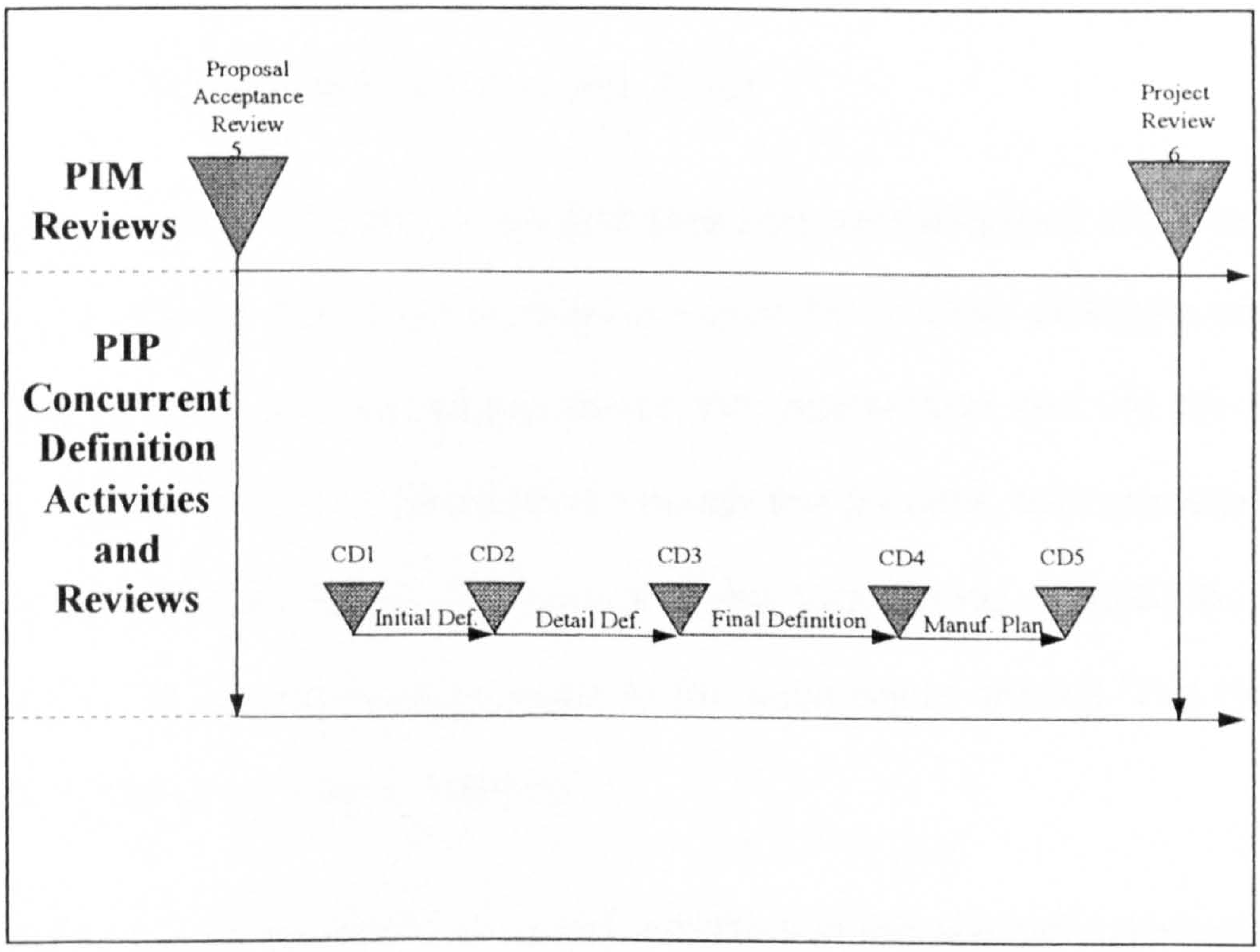

Figure 18. Concurrent Definition Process Activity Check Gates

Research results from this project show the demonstration of the benefits of a low-level process in the NPI activity. The application of process mapping to the NPI process has also been explored, including an analysis of process mapping techniques. This has resulted in process maps of the existing process being produced, and process maps of the new process, 'To be,' being developed. These have taken into account the development of tools and techniques required facilitating the process.

Company results from this work included the process mapping of the current NPI process, and the development of a 'to be' process. The implementation and testing of the proposed process by the pilot project team showed the acceptance of the ideas. The development of low level process procedures is key to the improvement of lead-time in the NPI process.

3.1.5 Key Differences Between 'As Is' and 'To Be'

The development of the 'To be' model addressed the critical issues identified in the 'As is' model. The key issues are summarised in Figure 19. The key problems are a mixture of organisational and process issues, where the organisation and the process do not support the quick transfer of information through the process, with numerous different transfer steps, passing in and out of control of the engineering organisation. A detailed explanation of the critical issues is given in the submission entitled 'The New Product Introduction Process' (Holmes, 1998iii).

The up front involvement of all necessary activities in the product introduction process was the major problem the people carrying out the process identified. Parallel or concurrent working was another area that the process was supposed to facilitate, but this again caused problems as the work tended to be done in functional groups rather than in the planned cross functional teams. Leading to a serial process rather than concurrent processes.

- Critical activities are out of control of the PIM team
- Very little work done concurrently
- Rig ordering is done in an ad-hoc way
- Lack of integration of manufacturing planning to the design
- Suppliers are introduced to the new design once the first review (PDR) has been completed

Figure 19. Critical Issues Identified in the 'As Is' Model

Formal procedures that actively encourage design iteration in the early stages were introduced in the form of signature requirements for drawings and documents. They did not actively encourage design iteration and improvement. The measures of performance implemented did also not support early iteration. This was also caused by the organisation structure where there was still the functional hierarchy, rather than the autonomous cross functional project team. This also hindered the aim of improving cross functional team communication.

Figure 20 shows the planned outcomes of the process. Duplicate tasks were removed through the use of a process to map the product development process, but there were major problems in integrating the information technology tools so they could pass information. This was particularly noticeable between the design and production planning software. The manufacturing planners had to redraw the product design in their software to produce the manufacturing plan.

- To ensure meaningful up-front involvement of all necessary disciplines in the design process
- To undertake parallel working to reduce lead times and the need for downstream changes
- To introduce formal procedures that actively encouraged design iteration in the early stages
- To ensure levels of communication that actively enhanced project team integration
- To eliminate duplicate tasks
- To stimulate cost effective designs by the continuous feedback of actual costing data
- To provide good planning, monitoring and control by:
  - Enabling early and accurate resource requirement estimates
  - Provide interim monitoring milestones
  - Rationalising sign off procedures
- To provide the right data at the right time in the right format for the receiver

Figure 20. Planned Outcomes of the 'To Be' Process

The continuous feedback of actual costing data was introduced through the application of project and program management. With project control over the entire project it was far easier to monitor project cost and product cost against planned milestones. The monitoring of these two activities are part of the mandatory measures of performance for PIM. The use of project and programme management, coupled with a generic process, increased the provision of good planning, monitoring and control. This was achieved by the project manager being able to plan the activities required for the project according to the process.

The use of the PDR and CDR milestones whilst identifying critical approval points in the process have not provided enough control over the process in order to allow the project to be dynamically monitored. For large projects there was considerable time delay between PDR and CDR. One of the example 'As is' projects had a gap of over 12 months between the two review points. Though this would rationalise the sign off approvals required to just two, the sign off review meeting became very large with large amounts of data having to be reviewed and approved. Problems emerging at the review meetings were then critical because of the amount of time involved prior to the meeting and the serial functional nature of the organisational approach to the process.

The final point about providing information at the right time in the right format for the receiver stems from the concept of internal customer and suppliers. The concept of using a multi functional autonomous project team to deliver new products should mean that information is generated and passed within the team informally in a manner that is acceptable to the members of the team. The team should be working together to deliver the product, not as a series of functions which is how the internal customer and supplier model works.

4 Facilitation Projects

This section of the report examines the project completed to facilitate the new process.

4.1 Early Supplier Involvement

The value of involving suppliers at the earliest stage possible in the design of a new product, particularly in the automotive industry has been extensively discussed (Hines, 1994). The work of this paper re-emphasises that value and then progresses to discuss the various ways supplier could be integrated into the product development process. The major areas covered include the use of stage release to pass partial information to suppliers in order to promote concurrent engineering, and the inclusion of key suppliers at major review points.

The need to involve suppliers at the earliest opportunity in the NPI process had been recommended from the high level design project, but no details as to the mechanism to be employed in the process had been given, hence the need to run a detail design project. The project is discussed extensively in the submission entitled 'Early Supplier Involvement' (Holmes, 1998vi).

The Case Study Company is a first tier supplier, as it supplies to the airframe manufacturers. The production of prototypes is part of getting involved in the airframe manufacturers NPI cycle. The involvement of the suppliers to the Company would effectively introduce second tier supplier integration, making the supply chain far more responsive to engineering changes from the customer.

4.1.1 Research Process and Methodology

Whilst the high level recommendations for early supplier involvement, attribute the benefits of this to the NPI process, the mechanisms for the facilitation and control of early supplier involvement had to be developed. The methodology for the development and implementation of this concept is given in Figure 21. The initial step was the identification and forming of the project team. This was made up of functional representatives from purchasing and design, both part time, with the RE acting as facilitator and project leader. The objective of the project team was to develop the mechanisms and ways that purchasing and suppliers could be integrated into the process and to develop in detail the methodology to facilitate early supplier involvement. The methodology would be developed within the project team, and then reviewed, with any issues being addressed before presenting the findings to the organisation and then to key suppliers.

4.1.2 Data Collection and RE's Contribution

The RE was responsible for the project management of this project, making sure that the recommendations from the high level project team were incorporated into the objectives of the project and that they were achieved in a timely fashion. The RE was also responsible for the linkage of this project to the other detail design projects occurring within the organization, as many had cross project impact. Examples of this include the linkage of this project to the staged data release project, where suppliers would receive different levels of information. The RE was responsible for the production of the detailed methodology and procedures. The responsibility for the pilot and full scale implementation of the project lay with the Case Study Company. The RE did not have the position within the organisation to actually implement the change.

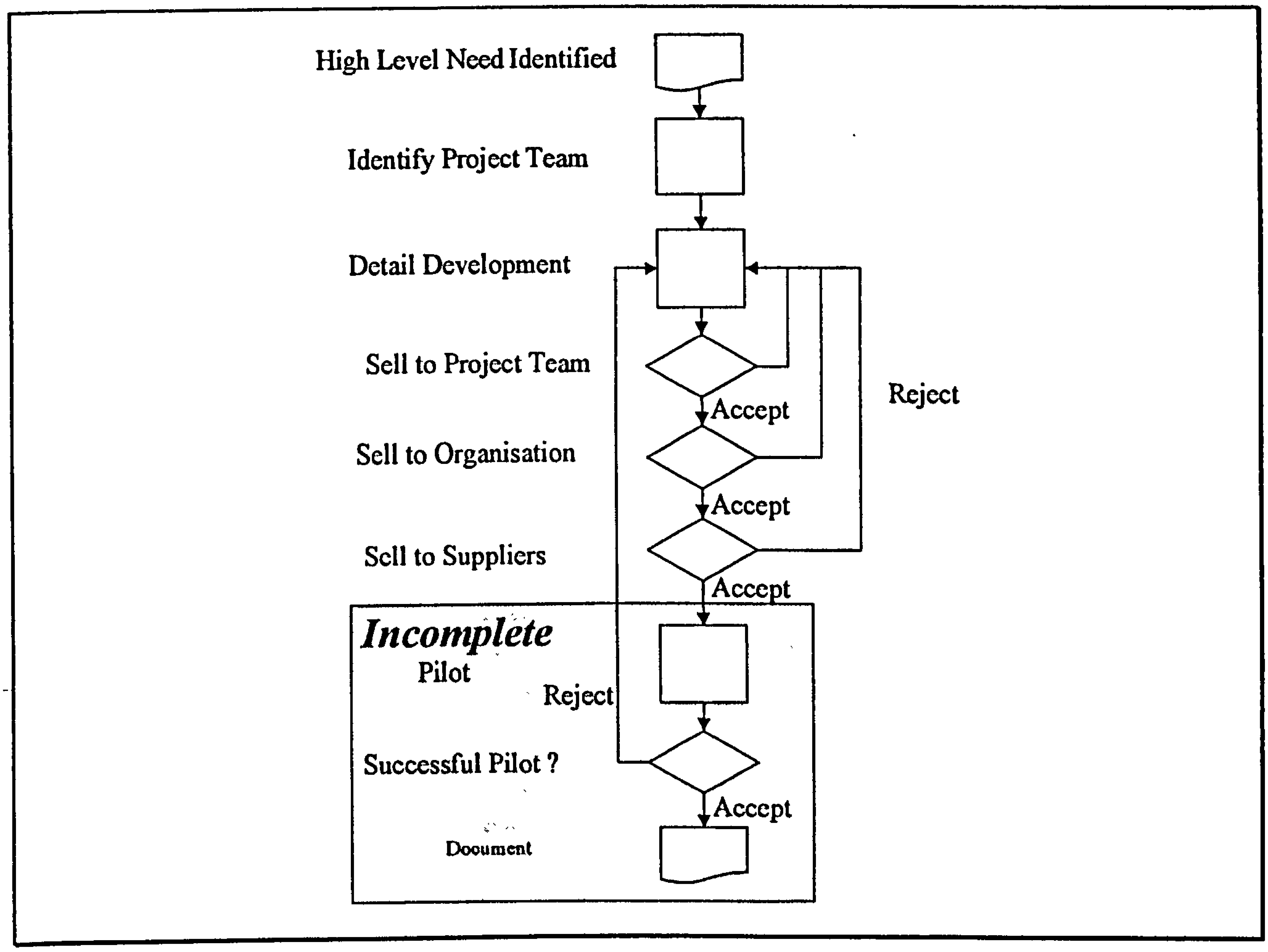

Figure 21. Early Supplier Integration Detail Design Methodology

The project leader form purchasing, using his existing supplier contacts, was responsible for the data collection. Initially this was a series of informal discussions with suppliers to understand their problems and concerns with becoming involved at an earlier date with the product development process.

4.1.3 Results and Level of Validation

Due to the reorganization at the Company, the Early Supplier Involvement project did not get past the informal discussions with suppliers. Those suppliers that were approached were all generally in favour of the principle of becoming involved earlier in the product development process as it gave them more time to do their own engineering. However there were a number of concerns that were raised by the suppliers.

One of the key concerns from the suppliers was the whole purchasing arrangement the Company had with its suppliers. The key problem being the late payment of suppliers. In order for the suppliers to become involved at an earlier point in the project they were asking for assurances that the payment of invoices be on time. In order to facilitate the payment of suppliers on time, a project examining the purchasing department's processes would need to be conducted – outside the scope of the product development redesign project. This issue had not been resolved when the reorganisation occurred and the project was suspended.

4.2 Organisational Learning

The need to retain knowledge within the organisation is being seen as one of the critical requirements for today's industry (Hayes et al., 1988). In order for industries to compete in a fast changing environment the need to have access to information generated within the organisation is paramount, without having to redevelop that information. The project entitled organisational learning examines the benefits of knowledge transfer, the varying types of knowledge within an organisation, and a review of the tools necessary to collect this information within the organisation.

4.2.1 Research Process, Contribution and Methodology

The methodology is shown diagrammatically in Figure 22. The process to be followed started initially with the identification and formation of a project team, who would then develop the detail methodology using the high-level design project guidelines. The methodology would then be detailed and proceduralised by the RE, and presented back for approval to the project team. Once approval from the project team had been obtained the methodology would be presented to the affected parts of organisation for approval. Once approval had been gained the methodology would then be piloted on available projects, and upon successful completion of the pilot the methodology would be 'rolled' out to the organisation.

The project team was made up of part time representatives from various functions: design, manufacturing engineering, and development, with the RE's role being project manager. The project team was used to validate the ideas developed by the RE, and to review their suitability for implementation. The key ideas were worked out within the team, with the RE then detailing the process and writing the procedures.

4.2.2 Results and Level of Validation

This project was completed with the detailed process procedures being produced. Of the two types of knowledge within the organisation targeted both had pilot projects run so as to demonstrate the benefits of the methodology. The full benefits of the methodology would not be seen immediately as due to the nature of the project, which was to collect and retain knowledge. There would be some time lag whilst the knowledge database was populated. However the pilot projects demonstrated the potential benefits of the methodology.

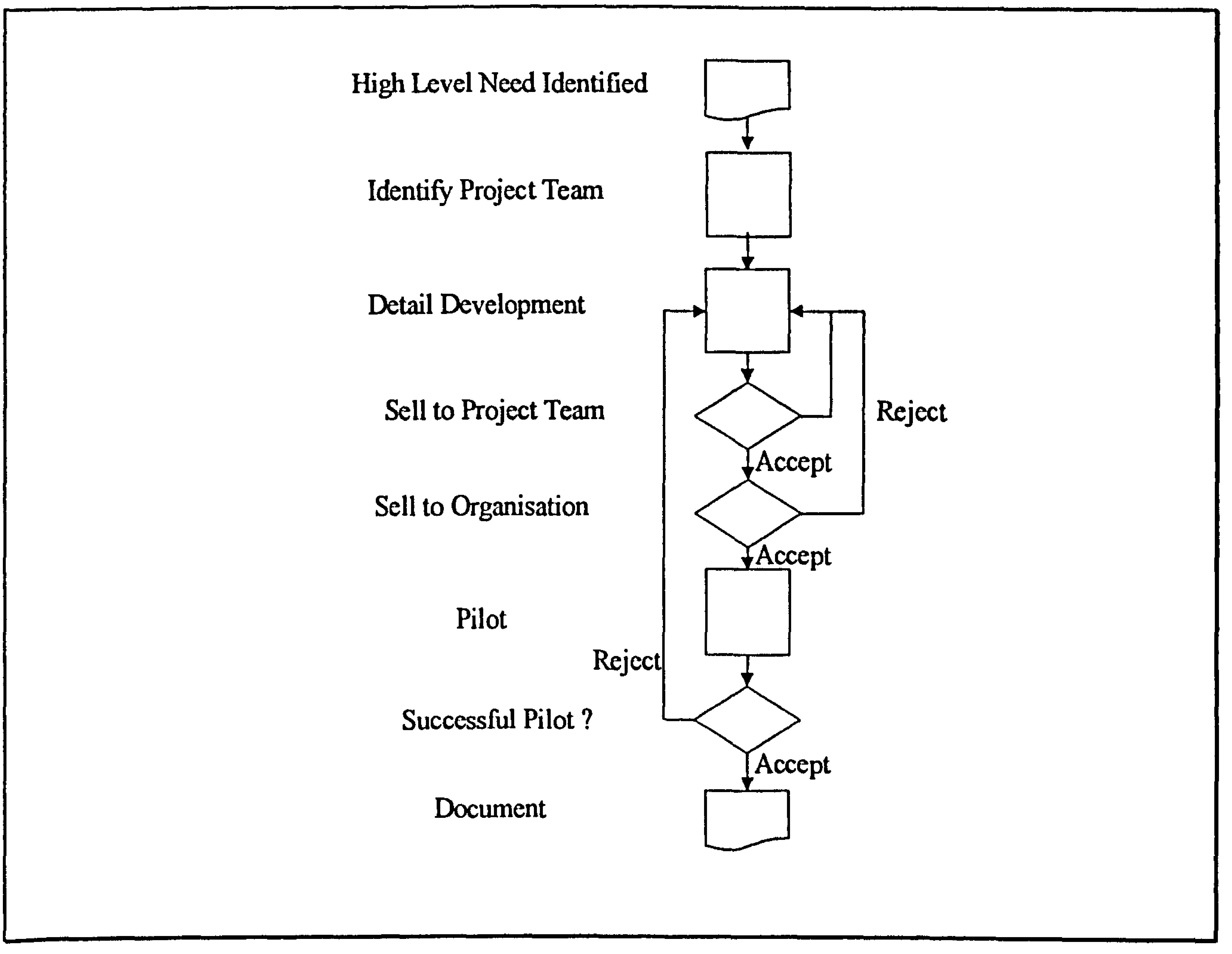

Figure 22. Organisational Learning Detail Development Methodology

Research results from this work show the benefit of information sharing and knowledge transfer within the organisation. This work completes the gap left in the companies traditional project life diagram, detailed in the submission entitled 'Organisational leaning in the NPI Process' (Holmes, 1998iv), where there was no transfer of information from a completed project to the next project.

A specific methodology for the transfer of knowledge within the organisation was developed which is also universally applicable. Two types of knowledge transfer were developed, the first being the transfer of knowledge from one project to another through the use of project briefings and debriefings. Here information would be gained from one project and the key points distributed to another project. This was piloted within the design function whereby problems within one project were documented and disseminated to another project, which was just starting. This proved successful as a number of key points were embraced leading to problems being avoided.

The second was the use of generic checklists at various check points through the product introduction process (Included in the submission entitled 'The New Product Introduction Process'). These were developed to support the product development process procedures to act as a check on the progress of the project and to also document the problems and solutions that had been uncovered during the course of that particular activity. The actual benefits to the organisation in terms of lead time, cost and quality are very difficult to quantify, but the literature supports the view that this work is beneficial (Thompson, 1995; Senge, 1990; Scarborough, 1996). The quantification of this may be part of further research. This could be quantified by analysing the use of previous project checklists as benchmarks for current projects to measure the prevention of 'making the same mistake twice.' This would enable cost, time and quality savings to be quantified.

4.3 Staged Data Release

Concurrent Engineering (CE) is now widely recognised as an environment in which overlapping phases of design and development activities shorten time to market, with higher levels of quality and less rework (Wilding & Yazdani, 1997). Practice of CE, however, requires careful planning of the implementation infrastructure in order to facilitate the management of technical and commercial risk. This paper presents a case study to demonstrate the principles and application of staged data release in the design and development of aerospace control systems. The methodology described was piloted within the Company on specific components.

4.3.1 Research Process, Contribution and Methodology

The research process followed is shown diagrammatically in Figure 23. This shows the various steps required for the completion of the project. The initial task was to identify the project team. This was configured of representatives of all areas affected by the process change – design, manufacturing planning, prototype production and development engineering. The representatives from the various functions were all part-time on the project.

The structure of the project was that the project team developed the key attributes of the process, with the RE developing the detail and including the process in the process procedure. The RE was also responsible for tracking the progress of the pilot project through the various functions and ensuring that the staged information release occurred.

4.3.2 Results and Level of Validation

Whilst the process was being detailed, an opportunity to pilot the process arose. A contract for a valve block system had been won. Members of the staged data release project team were seconded to the valve block project team and were keen to pilot the staged data release methodology.

The valve block project was planned in detail, and the various stages of information release agreed amongst the project team. Normally the release of information would be done in a serial manner between the various functions, but with the use of staged data release partial information would be released allowing the adoption of simultaneous engineering principles- two or more different functions could be working on the project at once. The planning of the staged data release took longer than the normal project planning, due to the increase in the number of steps in the process.

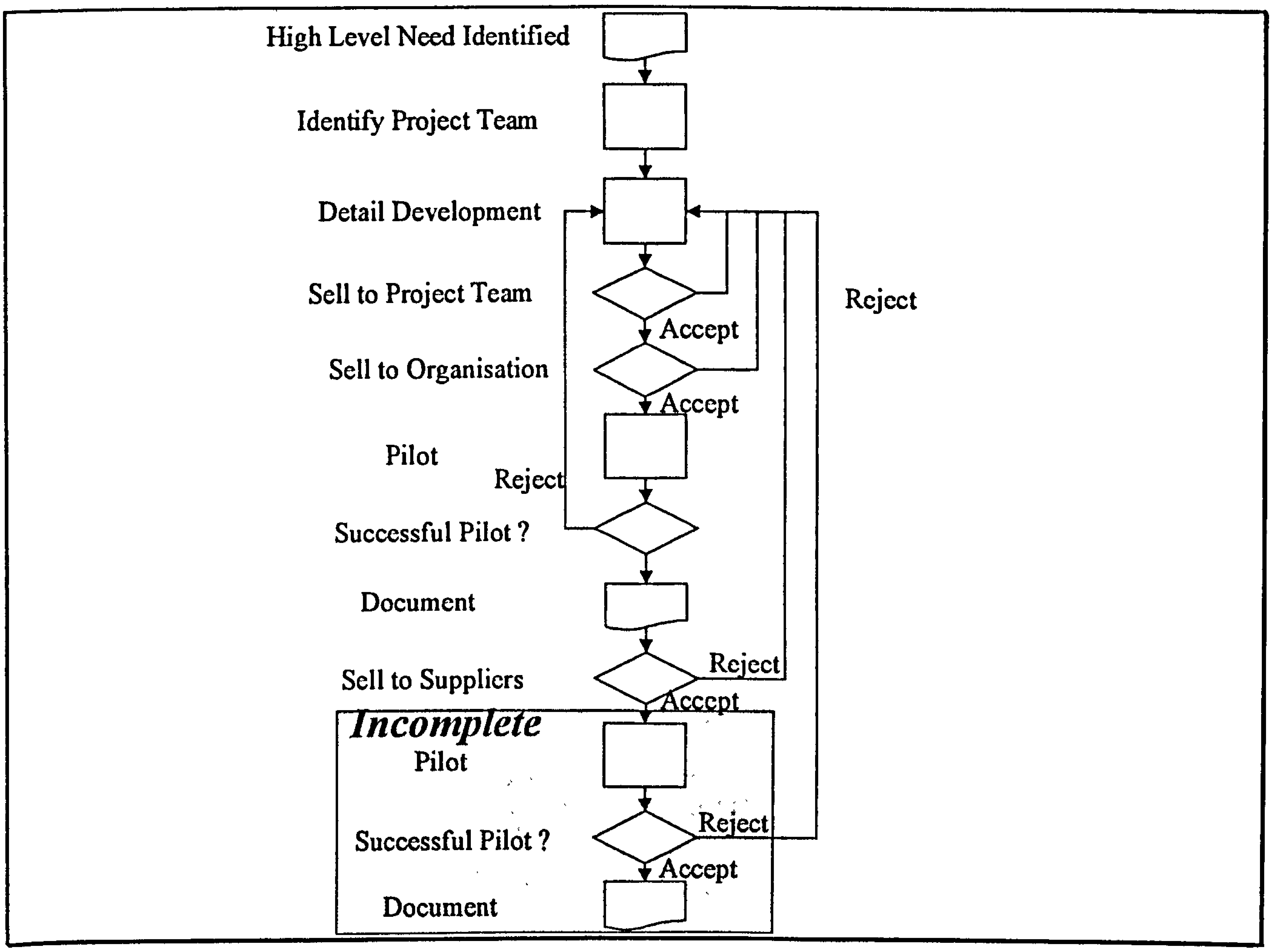

Figure 23. Staged Data Release Detail Development Methodology

The actual pilot project worked very well – with information released to the next function according to the information release plan. However this was only piloted up to the prototype production phase, that is between the design, manufacturing planning, and the cast supplier. The operations group could only accept a full package of information before commencing production, as they needed the completed casting – staged date release could only work up to this point. Whilst this was a set back, as the whole process was not validated, the lead-time improvements between design, manufacturing planning and the casting supplier were noticeable.

Benefits of the pilot project, apart from the reduction in lead-time, included the increase in communication between the various functions, with downstream problems being identified much earlier than with the traditional serial process. Specific analysis of comparable data is extremely difficult, as previous project lead-time data is either non-existent, or incomplete. For this particular valve block project, the project manager estimated a lead-time saving of approximately 50% over traditional projects.

Whilst some of this can be attributable to the visibility of the pilot project to the organisation, it is clear that there are tangible benefits from the implementation of staged data release. The actual lead-time reductions have come from two major sources, firstly from the stage release of information from detail design to manufacturing planning. And, secondly, from the involvement of suppliers and sub- contractors at an earlier stage in the development of the component.

The completion of the first pilot project justified the inclusion of the staged data release concept into the process procedures. The work on staged data release has resulted in the development of a company specific methodology for the decrease of lead times for key components passing through the new product development process. This methodology has been designed specifically to support the re-engineered product introduction process (Holmes, 1998iii).

4.4 *Time as a Dynamic Performance Measure*

With the focus of the research being placed on time reduction in the new product development process, there was a need for the application of suitable metrics to support this. Time is widely recognised as one of the most critical elements in the product development (Smith & Reinertsen, 1991; Stalk & Hout, 1990, Bower & Hout, 1988) and yet can be one of the most difficult to measure dynamically (Meyer, 1993, Dimancescu & Dwenger, 1996)

With the advent of the focus on time reduction in many companies, the traditional time, cost, quality triangle has been seen to become destabilized (Womack et al., 1990; Smith, 1990) This triangle suggested that time could only be reduced with an increase in costs and decrease in quality. As Gregory & Rawlings (1997) have discovered this is not the case. A focus on lead times has seen a decrease in costs and an increase in quality.

The detailed paper produced, 'Time as a Dynamic Performance Measure within the New Product Introduction Process' (Holmes & Yazdani, 1998i), disseminates the use of time as a dynamic metric within the product introduction process. It is based on the implementation of a new product introduction process within an aerospace systems supplier, and the need to give emphasis to time at the project engineering level.

4.4.1 Research Process, Contribution and Methodology

The research process followed a similar pattern to the other detail design projects. The high level need had been identified form the high level design project, with a recommendation that a performance metric be developed and taken to levels where the product development team can understand and control the full impact of engineering decisions upon the project plan.

The research process is shown diagrammatically in Figure 24. This shows the first step as identifying the project team. In this project, the project team acted as more of a steering committee with the RE completing the research and development and then presenting his findings to the project team for approval. The project team was made up of functional heads and principle engineers from the design and product integrity functions.

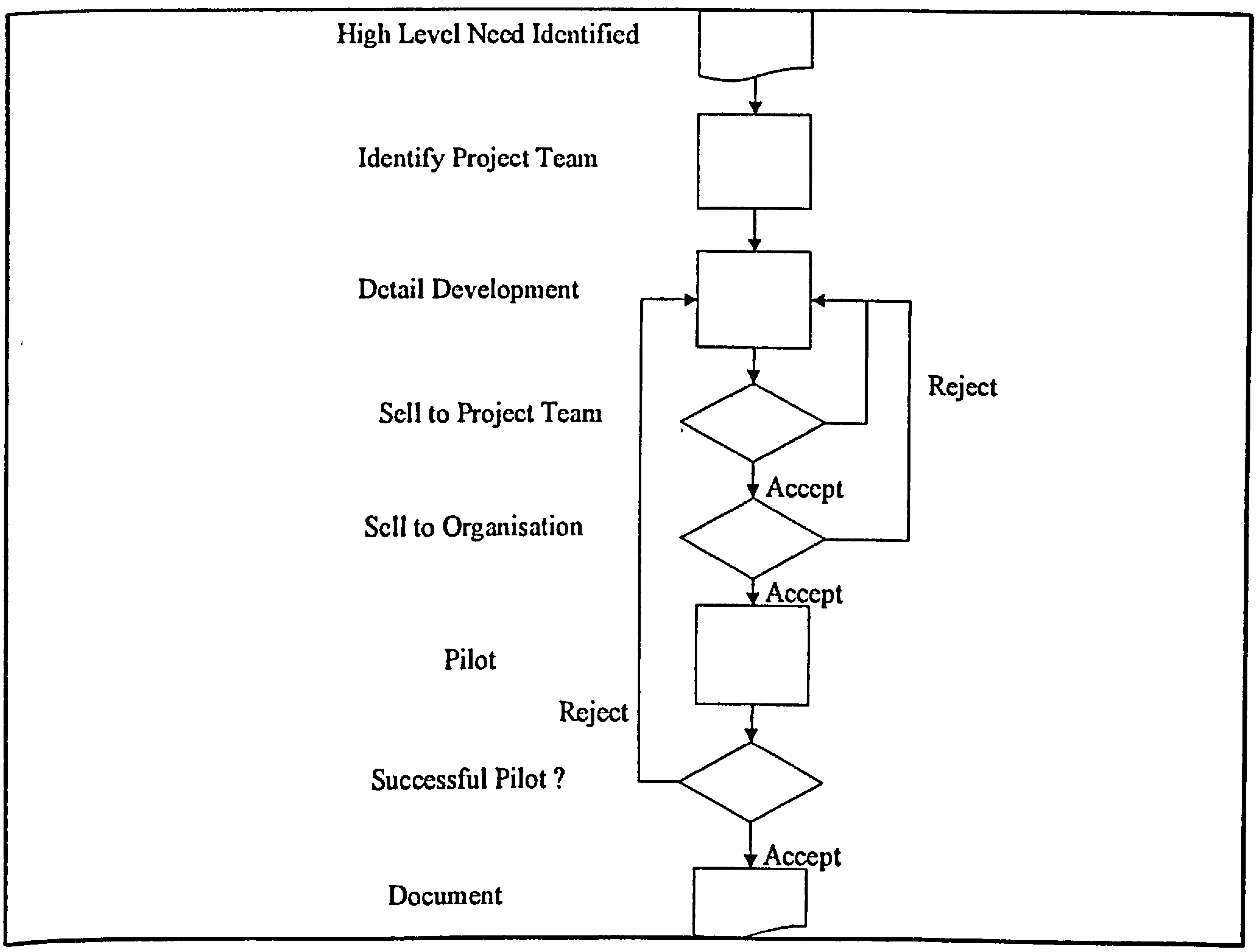

Figure 24. Time As A Dynamic Performance Metric Detail Development Methodology

Once the project team had agreed the principles and process, the next task was to 'sell' the concept and process to the organisation. This initially targeted the design function, with a pilot project being run. The successful completion of this would lead to roll out to the other functions. The pilot within the design function was successful, but the roll out to the other functions did not occur due to the organisational changes detailed earlier.

4.4.2 Results and Levels of Validation

Due to the application of the methodology within just one function, the process has not been fully validated. However the successful application of the process within a single function can be taken as a good indication that the methodology can be applied throughout the organisation.

Research results from this project have yielded a generic methodology suitable for application to many product development processes. The exact limits of the application of the metric are an area for further research. Actual results show that time can be measured dynamically and provide useful, visible information, to all levels within the organisation. The methodology was developed specifically to support the introduction of the new product introduction process at the Case Study Company. This was to allow the members of the team far more access to lead time information pertaining to the project under consideration.

A conclusion drawn from the research are that time can be measured dynamically and provides universal, practical and visible information to all levels within the organisation. The methodology developed proposes the use a calendar arrangement on drawings and documents and is particularly suitable for a concurrent engineering environment. This could also be adapted for sequential engineering. The proposed methodology combined with time based process mapping can provide valuable information for process improvements. Though the approach was introduced in the aerospace industry, other industries, such as automotive, are adopting this type of dynamic measurement approach to time.

4.5 Other Projects

In order to facilitate the introduction of the new process a number of other projects were carried out that are included in the portfolio. These are described in this section.

4.5.1 Internal Drivers for Process Improvement, Time Compression and Cost Reduction: An Aerospace Case Study (Holmes, 1998v)

This project focused upon surveying the members of the Engineering department to understand the process they currently applied to draw the 'As Is' process map, and to survey where their key problems were. The results of the survey were then used to aid the development of the 'To Be' model. The key issues identified in the department are given in Figure 25. The scale gives the actual number of comments relating to the issue.

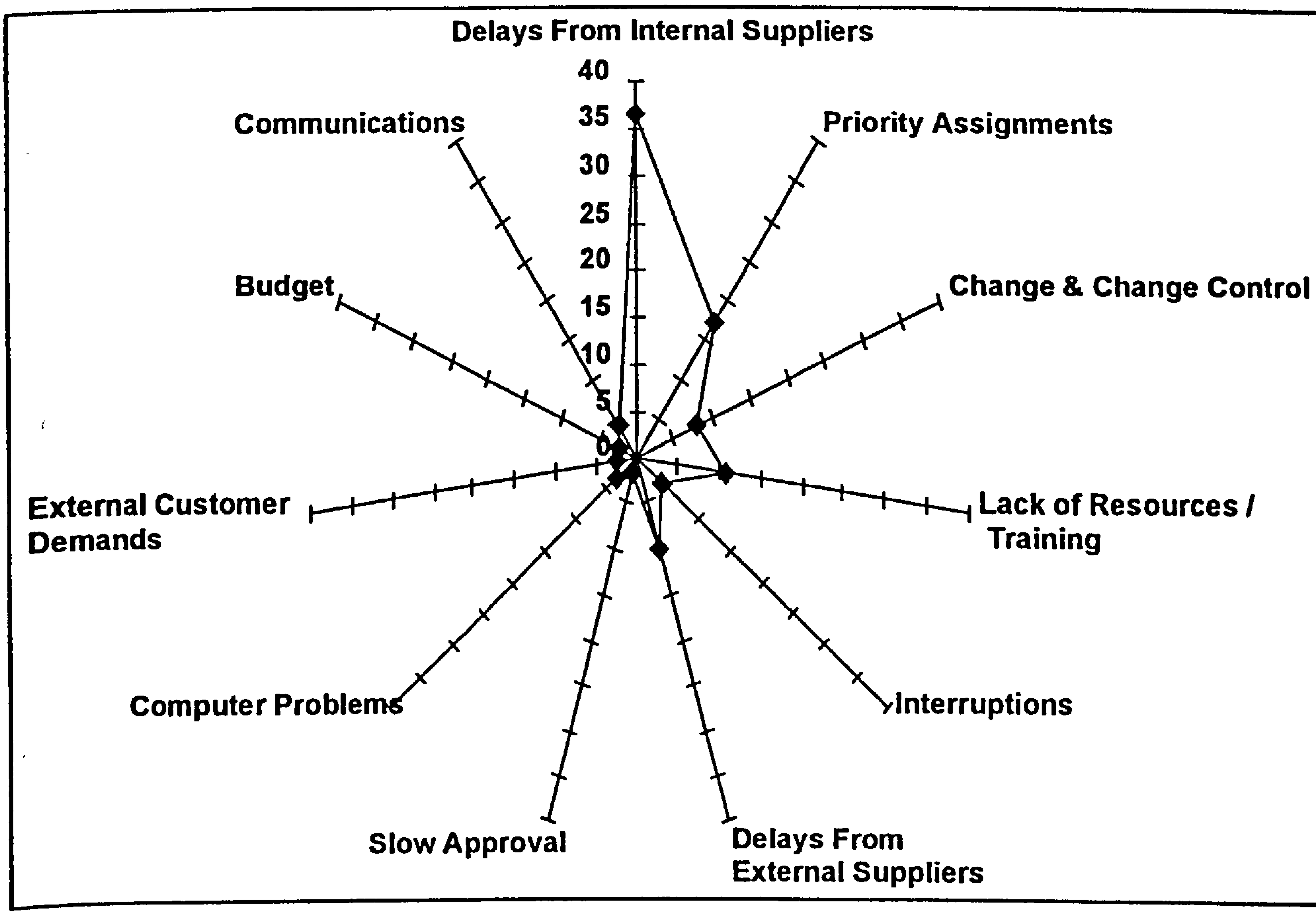

Figure 25. Issues Identified in the Engineering Department

The key issue identified is that of delays from internal suppliers. These are the problems of getting information passed from one functional group to the next. The recommendations for improvement for the engineering department are given in Figure 26. In terms of improvements that the engineering department would like to see implemented, the key point was earlier / more involvement in the project. In terms of the research framework provided, this submission is included in the people section.

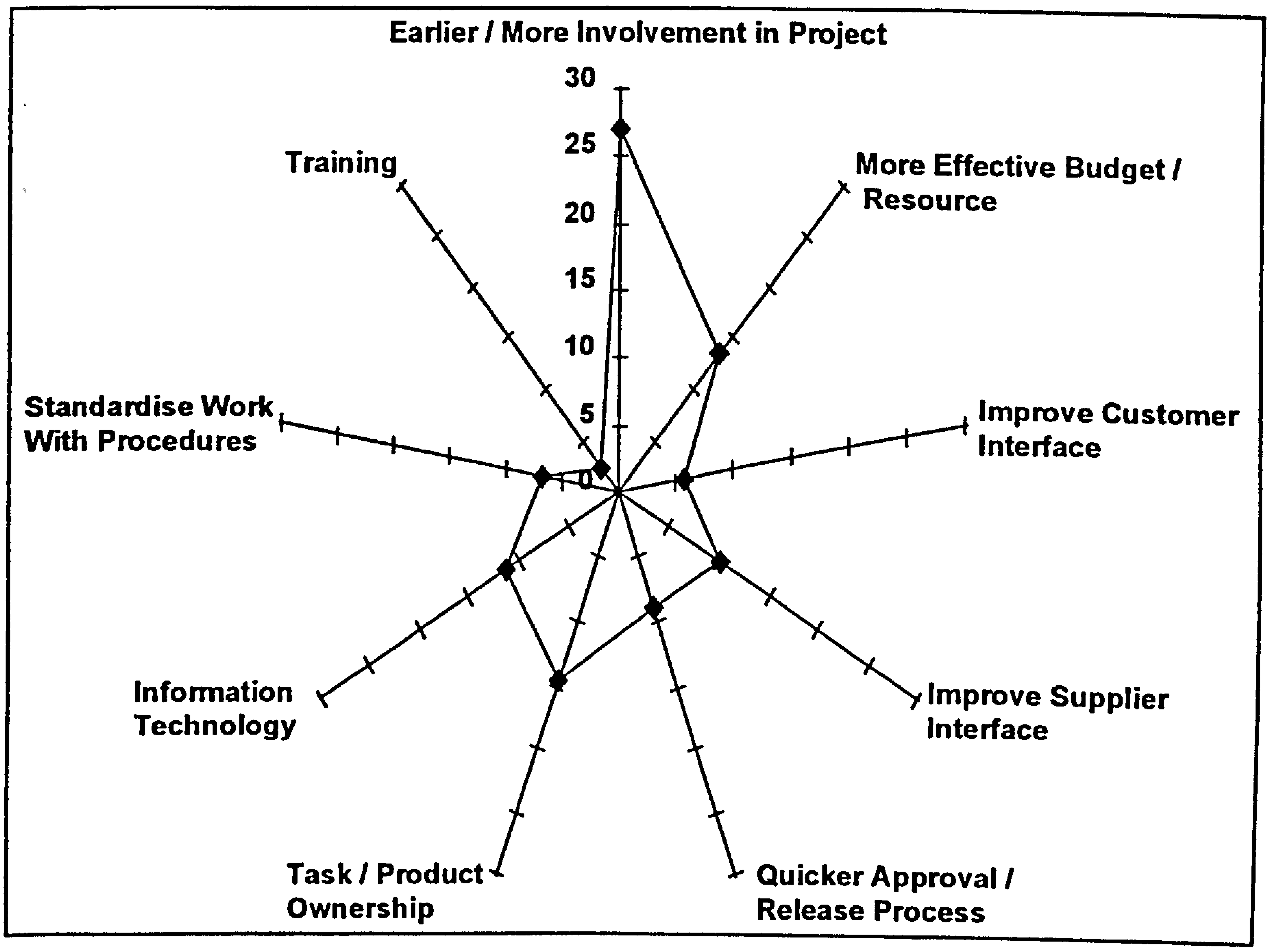

Figure 26. Recommendations for Improvement

4.5.2 Organisations for NPI (Holmes, 1995)

The research framework listed one of the key points as being organisation. This area of research focused on identifying the current practices for structuring organisations for effective new product introduction. A literature review was carried out to identify the current practices for structuring organisations and is presented in this submission. Four key organisational structures are identified: functional, lightweight matrix, heavyweight matrix, and project team. The advantages and disadvantages of each of these types of process are then described. Initial recommendations are also made as to how the case study Company should structure to reduce lead-time. This suggests that the organisation should move from the functional / lightweight matrix structure to a project team structure. The development of the process assumes that the organsiation will be project team based when the process is fully implemented.

This research was carried out very early in the programme, and requires some rework for it to 'fit' the rest of the portfolio. This rework is described in detail in section 5.3.

4.5.3 The Management of Process Change (Holmes, 1998ii)

In order for the process to be fully beneficial to the company, it would need to be implemented. This submission addresses the area of implementing the new process and discusses the various ways in which the new process could be introduced. The process used for introducing the change at the case study Company is reviewed, and compared to the company change methodology. Various tools are described in how they aid the implementation of process change. The application of a process mapping methodology is also discussed.

A change process methodology is proposed and key areas for successful change discussed. These include the need for top level support, clear communications, project continuation, clear objectives, use of applicable tools and techniques and piloting for success.

5 Results

This section introduces the results of the research project for both the Case Study Company and the research field. Areas for rework identified from earlier portfolio submissions are also presented here, and the section finishes with a discussion focusing on areas for further research.

5.1 Benefits to the Case Study Company

The full potential of the project has not been realised due to the organisational changes that occurred to the organisation whilst the research project was in progress. However, the company has the potential to benefit enormously from the work carried out, in that a fully documented and proceduralised product introduction process is available for use. The techniques to facilitate this process have been developed and are in place and the various quality regulations regarding the use of the tools and techniques have been addressed.

Actual benefits to the organisation are the researched existence of demonstrated robust paths of implementation giving confidence to the management and workforce. These are summarised in actual deliverables as:

- The 'As is' Process Map
  - A detailed description of the current process for the introduction of new products, including functional responsibilities and current lead times.
- The 'To be' Process Map

- A detailed description of a new process to facilitate the introduction of new product within a much shorter lead-time.

- An Internal Description of problems

  - A detailed description of the current issues that cause delays and problems to the current new product introduction process

- Internal Recommendations for improvement

  - A detailed set of recommendations and methods which address the current issues with the New Product Introduction process

A new process for the introduction of new products has been developed and proceduralised addressing the concerns of the people working in the current process.

The projected lead-time savings of implementing the new process would yield an estimated 50% lead-time reduction. The implementation of the concurrent definition process would yield an 18% reduction in lead-time for that specific part of the process. This is made up of improvements derived from dedicated team working, improved information flow, generic process control through procedures and the application of the tools and techniques described earlier. The overall figures shown are based upon interviews with the project team as to how the new process would affect the development of new products. In order to measure the affect of the new process a number of projects would need to be run from contract award to manufacturing handover in order to measure the affect of the changes. Due to the 2-3 year timescales of the development process, this was not possible within the timeframe of this research project.

To realise the remaining 32% the other projects - prototype production and assembly, test and qualification would need to be implemented. This is shown in Table 1.

Table 1. Lead Time Reduction

• Concurrent Definition		18%
• PIM extended to prototype product		22%
• Simplification of assembly & test		10%
	Total:	**50%**

Projected cost savings are very difficult to estimate, and whilst an exercise to calculate the cost savings of the new process was carried out, this just relied on reducing the current quality costs, through reducing rework due to improved information transfer between the various functions represented on the team. These do not include the enormous impact that reducing lead-time dramatically would have on the organisation.

5.2 Benefits to the Area of Research

The benefits of this work to the research field, apart from the individual development of the RE, have been the development and testing of various aspects of theory. These are given below:

- Development and testing of a low level process

  - This was the key finding of the research and the most detailed, with a low level process having been developed and tested to reduce lead times.

- Development and testing of supplementary tools and techniques to support the process:

- Staged data release

- Organisational learning

- Early supplier involvement

- Development of performance metrics

Whilst the concepts of these may exist in the theory, the benefit to the research is in the actual testing, and the lessons learned from it.

5.3 Areas for Rework

The submission entitled 'Organisations for New Product Introduction' (Holmes, 1995) surveys the current thinking for the structuring of organisations to facilitate the introduction of new products.. The report examines the five main generic structures for organisations: functional, lightweight matrix, balanced matrix, heavyweight matrix, and team structures with information on multifunctional teams and multifunctional team members. The report validates the organisation point in the NPI framework.

However, this report was produced at the initial stages of the research, and is weak in addressing a number of areas. Greater detail could also be provided about the organisational structures suitable for product introduction, especially with the experience gained of working within the structures discussed.

The linkage of the organisation structure with management, process, tools and techniques and people needs to be developed further. This could be achieved by examining the requirements for different organisational structures against types of management and process.

This report also under estimated the task of introducing change to a 'traditional' engineering firm.

5.4 *Areas for Further Research*

This section of the report identifies the areas for further research identified whilst conducting this research.

1) Whilst the value of the product development process developed has been shown theoretically and demonstrated by pilot projects, there is the need to implement the process fully, and to measure the benefits of a full product introduction project, with all the supporting tools and techniques in place. In order to be able to do this a considerable amount of time (three years) is required for just one project. Three years would allow for a complete product introduction project to be monitored. In order for a new product introduction process to be developed for another, similar type of company a lead time of four to five years would be required to allow the process to be developed, implemented and measured.

2) The detailed development work of the prototype production and assembly, test and qualification phases of the project needs to be finished. Whilst the high level design has been completed the detailed process procedures still need to be completed. However the complexity of these two areas when compared to the concurrent definition phase of the project should make them easier to develop. In order to complete these phases a similar approach of that use in the concurrent definition phase should be applied.

3) The move towards becoming a process based organisation, whilst starting in the product development process, needs to be explored as it is implemented through the

rest of the business processes. The need to examine the business process transitions becomes critical to allow the business to function as a seamless enterprise. A series of user group meetings should be used to monitor the change to a process based organisation where issues to the change are highlighted.

4) Whilst the initial versions of the tools and techniques developed have been seen / proven to work, further development of these will be necessary to take into account new technology. Examples of this could be the use of the Internet as a source of passing information through to suppliers, or suppliers allowing access to their delivery schedules to the product development team. This is an area that requires much further research.

5) The examination of the use of the product data management system (PDM) and how that is linked to the product development process is a major project, but one that could realize major improvements in terms of information sharing and project control. This also needs to be linked of the use of document management systems and the revision control systems that can be implemented with them. The research needs to focus on the implementation of new technology and its affects upon the organisation. This could be done by examining the role of the new technology and analyzing how it affects the current method of operation. Tools that just improve one particular function are not really the focal point of this research, but tools that span a number of functions and facilitate the whole process should provide the target for this work.

6 Conclusions

The conclusions for each of the individual projects are given in the respective submission, the aim here is to review the main conclusions of the innovation of the whole research project.

The contributions to knowledge are summarised below:

i) A new product introduction process has been developed specifically for the Case Study Company. This has involved the development of a detailed lower level process for application, which is an innovation within the industry sector.

ii) Tools and techniques to support the new process have been developed in both general and specific conditions. These include staged data release, organisational learning, time as a dynamic performance metric, and early supplier involvement.

iii) Significant potential improvements have been demonstrated at the Case Study Company through pilot projects.

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